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ARS/BLM COOPERATIVE STUDIES

Northwest Watershed Research Center
Boise, Idaho

Steve SCB

Interim Report FY-1992

Technical Report NWRC 92-4

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ARS/BLM COOPERATIVE STUDIES

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ARS/BLM COOPERATIVE STUDIES

Northwest Watershed Research Center
Western Region
Agricultural Research Service
U. S. Department of Agriculture
800 Park Boulevard
Plaza IV, Suite 105
Boise, Idaho

INTERIM REPORT

CRIS Work Unit No. 5362-11660-002-01R

October 1, 1991 to September 30, 1992

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INTRODUCTION

The Agricultural Research Service Northwest Watershed Research Center (ARS-NWRC) and the Idaho State Office of the Bureau of Land Management (BLM-ISO) have been conducting mutually beneficial research and studies in Southwest Idaho since the early 1960's. Much of the work has been conducted on the Reynolds Creek Experimental Watershed which is largely under the management authority of the BLM. The Reynolds Creek Experimental Watershed is the only major rangeland watershed research facility in the northwest and is operated by the ARS. Research conducted by the NWRC has included a variety of subjects such as: hydrology, water quality, vegetation management, hazardous waste management, climatology, erosion and sedimentation. Research contributions to rangeland management and hydrology at the regional, national and international levels have been significant. This productive relationship is currently continuing through cooperative rangeland research projects and technology transfer efforts.

This report is a summary of work conducted by ARS in accordance with the FY-1992 Interagency Agreement between the BLM-ISO and ARS-NWRC. Projects include: 1) Transfer of Modeling Technology (SPUR, WEPP and ERHYM models), 2) Germination Requirements of *Thelypodium Repandum* - A Federal C2 Species in East Central Idaho, 3) Germination Enhancement of Native Grasses for Restoration of Deteriorated Rangelands in the Great Basin, 4) Environmental Assessment of Rangeland Renovation (Greenstripping-Lockman study site), 5) Land Information System Development, 6) Modeling Hazardous Waste Migration, and 7) National Atmosphere Deposition Program.

COOPERATIVE STUDIES

1. TRANSFER OF MODELING TECHNOLOGY

ARS Personnel: J. Ross Wight - Range Scientist
Clayton L. Hanson - Agricultural Engr.
Leon A. Huber - Mathematician
Gerald Flerchinger - Res. Hydraulic Engr.
Stuart Hardegree - Plant Physiologist

BLM Personnel: Karl A. Gebhardt - Hydrologist/Env. Engr.

The ARS-NWRC 1992 technology transfer activities include:

1. A technology transfer workshop was conducted February 25-27, 1992 with Bureau of Land Management (BLM) personnel on the application and operation of the SHAW, ERYHM and other natural resource models and techniques for measuring and monitoring precipitation, temperature, wind and runoff.

2. The use of hydrologic and chemical transport models were used to aid BLM in assessing the potential risk for off-site contamination from chemicals deposited in landfill sites on BLM land.

3. Consultations and information material on the use of RANGETEK, SHAW (Simultaneous Heat and Water model), SPUR (Simulation of Production and Utilization of Rangelands model), and USCLIMAT.BAS (a weather simulation model) were provided to numerous action agencies, consultants, and scientists.

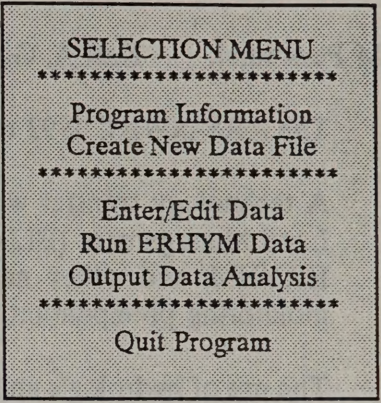
Following are extended abstracts of papers presented at the 28th Annual Conference and Symposium, Managing Water Resources During Global Change, an international conference sponsored by the American Water Resources Association, Reno, Nevada, November 1-5, 1992.

Extended Abstract

IMPROVING THE USEABILITY OF RANGELAND SIMULATION MODELS

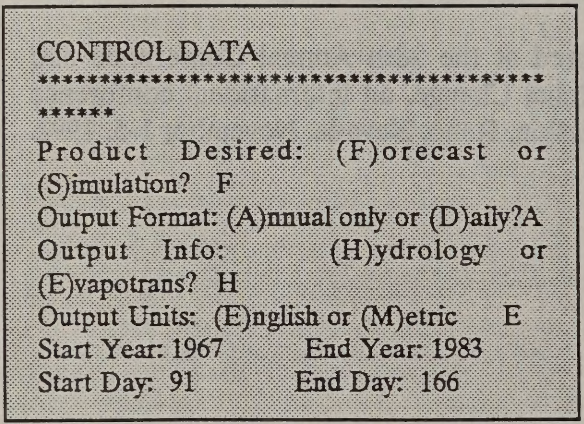
J.R. Wight[1]

Application of natural resource models has been greatly limited by the complexity of input requirements and output interpretations. The paucity of information concerning values for input variables and parameters requires extensive use of values estimated from published data or based on quantitative relationships with more commonly available information. For example, soil water content at permanent wilting and field capacity can be estimated from soil texture information. The preparation of complex input data files and interpretation of model outputs have been barriers to the application of models by resource managers. This extended abstract briefly describes RANGETEK (Wight, 1990), a decision aid for range management that makes extensive use of user-friendly menus, help screens, and expert system technology to organize input information and estimate input variables and parameters. Graphic analysis is available to interpret and display model outputs. RANGETEK is based on ERHYM (Wight, 1987), a climate, water balance model that calculates a daily water balance and a yield index based on the ratio of actual to potential transpiration.



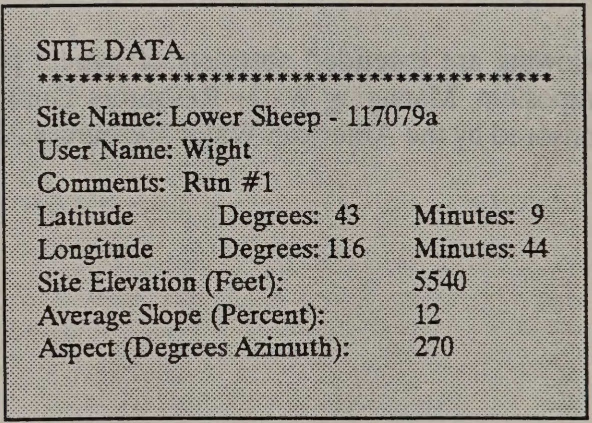
```
SELECTION MENU
************************

Program Information
Create New Data File
************************

Enter/Edit Data
Run ERHYM Data
Output Data Analysis
************************

Quit Program
```

Figure 1. Selection menu



```
CONTROL DATA
***************************************
******
Product Desired: (F)orecast or
(S)imulation? F
Output Format: (A)nnual only or (D)aily?A
Output Info: (H)ydrology or
(E)vapotrans? H
Output Units: (E)nglish or (M)etric    E
Start Year: 1967      End Year: 1983
Start Day: 91         End Day: 166
```

Figure 2. Example of control data screen



```
SITE DATA
**************************************

Site Name: Lower Sheep - 117079a
User Name: Wight
Comments: Run #1
Latitude        Degrees: 43     Minutes: 9
Longitude       Degrees: 116    Minutes: 44
Site Elevation (Feet):          5540
Average Slope (Percent):        12
Aspect (Degrees Azimuth):       270
```

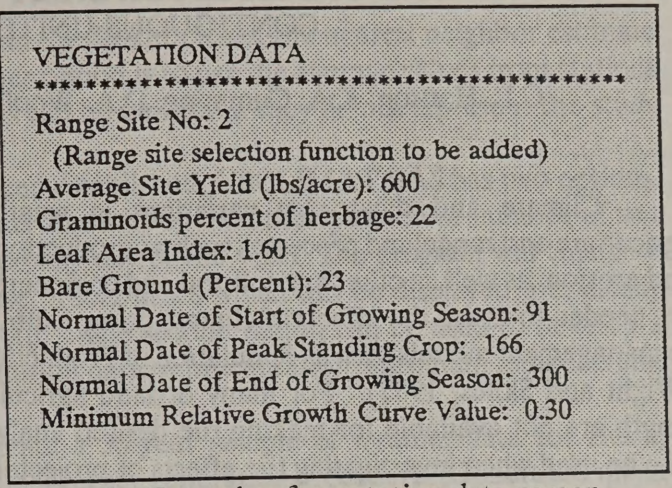
Figure 3. Example of site data screen

Upon program initiation, RANGETEK displays a menu screen (Figure 1) that lists seven options. The "Program Information" option provides some basic information on the operation and application of RANGETEK. The next two options allow the user to name a new data file or load an existing data file. The "Enter/Edit Data" option is used to enter data into the newly named file or edit the existing file. Upon the selection of the "Enter/Edit Data" option, four input data screens become available (Figures 2, 3, 4, and 5). These screens are self explanatory and all indicated data must be entered before the model can run. For each input variable there is a help-screen that can be accessed by pressing the "F1" key. Additionally, there is a graphic display to help describe an average seasonal growth curve.

---

[1] Range Scientist, USDA, Agricultural Research Service, Northwest Watershed Research Center, 800 Park Blvd., Plaza IV, Suite 105, Boise, ID 83712

There are several helps available for obtaining soils data. Bulk densities, permanent wilting and field capacity soil water contents, and runoff curve numbers can be calculated from inputs of percent sand and clay, organic matter, and cover information. Bulk densities and soil water contents can also be estimated from screen-displayed tables of average values for each textural class. Percent sand and clay can be estimated with the help of a displayed textural triangle or a routine that helps interpret soil survey sieve analysis data. The default values can be edited or replaced with available field data. The "Run ERHYM Model" option runs the model with the designated input data and climate files.

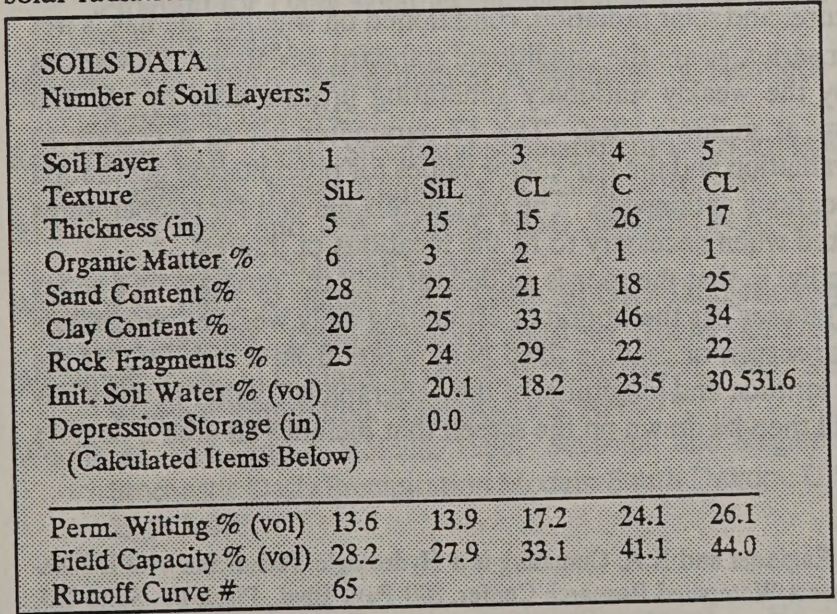

VEGETATION DATA
****

Range Site No: 2
(Range site selection function to be added)
Average Site Yield (lbs/acre): 600
Graminoids percent of herbage: 22
Leaf Area Index: 1.60
Bare Ground (Percent): 23
Normal Date of Start of Growing Season: 91
Normal Date of Peak Standing Crop: 166
Normal Date of End of Growing Season: 300
Minimum Relative Growth Curve Value: 0.30

Figure 4. Example of vegetation data screen

Selection of the "Output Data Analysis" (Figure 1) displays a screen with the following options: "View Data Input File"; "View Climate Input File"; "About Output Data"; "Load Output File"; "Print Output File"; and "View Data Output File". After loading an output file, it can be viewed on the screen, printed, or graphically displayed with model outputs on the y-axis against time on the x-axis.

RANGETEK requires inputs of daily maximum and minimum temperature, precipitation and solar radiation that are supplied by the climate file. If not available in the weather record, daily solar radiation will be estimated.


SOILS DATA
Number of Soil Layers: 5

Soil Layer	1	2	3	4	5
Texture	SiL	SiL	CL	C	CL
Thickness (in)	5	15	15	26	17
Organic Matter %	6	3	2	1	1
Sand Content %	28	22	21	18	25
Clay Content %	20	25	33	46	34
Rock Fragments %	25	24	29	22	22
Init. Soil Water % (vol)		20.1	18.2	23.5	30.531.6
Depression Storage (in)		0.0			
(Calculated Items Below)					
Perm. Wilting % (vol)	13.6	13.9	17.2	24.1	26.1
Field Capacity % (vol)	28.2	27.9	33.1	41.1	44.0
Runoff Curve #	65				

Figure 5. Example of soil data screen

References

Wight, J.R., K.A. Gebhardt, A.L. Huber, and C.L. Hanson, 1990. RANGETECH: A decision aid for range management, p. 179-185. In: E.B. Janes and W.R. Hotchkiss (eds.), Transferring Models to Users, Symp. Proc., Denver, CO, Nov. 4-8. Amer. Water Resourc. Assoc., Bethesda, MD.

Wight, J.R., 1987. ERHYM-II: Model description and user guide for the BASIC version. U.S. Dept. of Agriculture, Agriculture Research Service, ARS-59.

Extended Abstract

MICRO COMPUTER PROGRAM FOR DAILY WEATHER SIMULATION IN THE CONTIGUOUS UNITED STATES

C.L. Hanson, K.A. Cumming, D.A. Woolhiser, and C.W. Richardson[2]

Climate and day-to-day variations in weather have major influences on dryland agriculture and rangeland processes such as production, livestock water, insect dynamics, runoff, and erosion, as well as other agricultural and engineering management decisions. Weather data are needed to assess the effects of climate on agricultural and rangeland processes and as inputs to management models such as Simulation of Production and Utilization of Rangelands (SPUR) (Wight and Skiles, 1987). For many dryland agricultural sites, climatic records of sufficient length are not available for making the desired analyses. Generated climatic data series can also be used when investigating the effects of projected climate change on ecosystem dynamics. Therefore, it is often desirable to have the capability to generate climatic data series which have the appropriate statistical characteristics for a location.

In this paper, we give a summary of the microcomputer program USCLIMAT.BAS (Hanson, et al., 1992) which is an updated version of the program CLIMATE.BAS (Woolhiser, et al., 1988). USCLIMAT.BAS can simulate daily precipitation, maximum air temperature, minimum air temperature, and solar radiation. It can also simulate temperatures and radiation based on historical precipitation records.

The Markov chain-mixed exponential model (MCME) (Woolhiser and Roldan, 1986) is used to describe daily precipitation. Precipitation occurrence is described by a first-order Markov chain, and the amount of precipitation greater than 0.254 mm is described by a mixed exponential distribution.

Procedures used in USCLIMAT.BAS to describe the multivariate process of maximum temperature, minimum temperature, and solar radiation have been described by Richardson (1981) and Richardson and Wright (1984). In this model, the daily means of maximum temperature, minimum temperature, and solar radiation, conditioned on whether the day is wet or dry, are described by a Fourier series, as are the conditional standard deviations. Deviations from the means are modeled by the weakly stationary generating process used by Matalas (1967) for generating streamflow at multiple sites. The 17 parameter values necessary to generate temperature and solar radiation and the parameter values for precipitation generation are stored in disk files for 360 locations nationwide. The parameters needed for temperatures and solar radiation can be adjusted when necessary to fit the locations of interest.

The program is "user friendly" in that the user is guided through the program by a series of screen-displayed questions. The user has the option of estimating daily weather parameters from a grid map on the computer screen or reading fixed parameters from a disk file. If the user wants to use a grid map, the latitude and longitude of the geographical center of the study area must be entered. A map will then be drawn on the screen that includes an area 2 degrees north and south and 3 degrees east and west of the central grid location. Next, the arrow keys are used to move the cursor to the desired location and have two concentric circles of 48 and 161 km radii drawn on the screen.

---

[2] C.L. Hanson is an Agricultural Engineer and K.A. Cumming is a Hydrologic Technician with USDA-Agricultural Research Service, Northwest Watershed Research Center, 800 Park Blvd., Plaza IV, Suite 105, Boise, ID 83712; D.A. Woolhiser is a Research Hydraulic Engineer (retired) with USDA-Agricultural Research Service, Aridland Watershed Management Research, 2000 East Allen Road, Tucson, AZ 85719; and C.W. Richardson is an Agricultural Engineer with USDA-Agricultural Research Service, Soil and Water Research Laboratory, P.O. Box 748, Temple, TX 76503.

If there are one or more stations within the 48-km radius, the nearest neighbor estimate of the daily parameters can be used. The other option is to use the average values from stations within the 161-km radius. Any of the stations can be omitted if they do not represent the study site.

Once the weather parameters have been established, USCLIMAT.BAS has two options. The first calculates the probabilities of various amounts of total precipitation or number of wet days for an n-day ($n<30$) period beginning on any day of the year. The program will calculate the cumulative distribution functions of these probabilities which can be displayed graphically on the screen, output to a line printer or both. The second option can be used to develop a sequential file of n years of simulated precipitation data or precipitation, maximum temperature, minimum temperature, and radiation data.

USCLIMAT.BAS was used to generate a 30-year sample of weather data for Boise, Idaho, as an example of the application of the weather generation procedure. Generated mean precipitation amount and average number of wet days per month and year were very close to that of the historic record. Generated mean daily maximum and minimum temperature compared favorably with the observed data for most months. The greatest difference between the monthly maximum temperature was 4 ^{0}C for February and the greatest minimum temperature difference was 3 ^{0}C for February and August. Historic and generated mean annual maximum and minimum temperatures were within 1 ^{0}C. Simulated mean monthly solar radiation was within 2 percent of the recorded mean.

USCLIMAT.BAS is written in BASIC language and has been run on several different microcomputers. The program is available in diskettes.

References

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Richardson, C.W., 1981. Stochastic Simulation of Daily Precipitation, Temperature, and Solar Radiation. Water Resources Research 17:182-190.

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Wight, J.R. and J.W. Skiles (ed.), 1987. SPUR: Simulation of Production and Utilization of Rangelands. Documentation and User Guide. USDA-ARS, ARS-63.

Woolhiser, D.A., C.L. Hanson, and C.W. Richardson, 1988. Microcomputer Program for Daily Weather Simulation. USDA-ARS, ARS-75.

Woolhiser, D.A. and J. Roldan, 1986. Seasonal and Regional Variability of Parameters for Stochastic Daily Precipitation Models: South Dakota, U.S.A. Water Resources Research 22:965-978.

2. GERMINATION REQUIREMENTS OF *THELYPODIUM REPANDUM* A FEDERAL C2 SPECIES IN EAST-CENTRAL IDAHO

ARS Personnel: Stuart Hardegree - Plant Physiologist
Michael Burgess - Electronics Technician
University of Idaho Personnel: Mark Anderson - Research Technician

BLM Personnel: Caryl Elzinga - Botanist

Experiments were initiated during FY91 with support funds from the USDI-BLM Salmon District Office and continued in FY92 with support from USDA-ARS.

Background/Justification

Thelypodium repandum has been classified as a Federal Category 2 (C2) candidate species for proposed listing as endangered or threatened under the Endangered Species Act of 1973. C2 species are defined as those that we suspect should be listed as endangered but for which we lack substantial information as to their biological vulnerability. *T. repandum* is endemic to distinct soil sites in east-central Idaho. High variability in population size and distribution from year to year suggests that microsite conditions, microclimatic variability and seed germination response interact to determine successful regeneration. *T. repandum* sites may contain no reproducing individuals in any given year suggesting that viability of seed stored in the soil may be critical to long term population maintenance. *T. repandum* seed is thought to have low initial germinability which may suggest an after-ripening requirement or the need for physico-chemical scarification for successful germination. There is currently no information available regarding long-term seed viability or the specific conditions required for successful seedling establishment. In order to determine the biological vulnerability of *T. repandum*, more must be known about the interactions of seedbed conditions and seed germinability. There is evidence that some *T. repandum* habitat is at risk from road building and mineral exploration but the potential impact of these activities cannot be determined without further understanding of the population dynamics of this species.

Objectives

The purpose of this study was to develop baseline information on the germination requirements of *T. repandum*. Specific objectives were to:

1. Determine optimal temperature conditions for standardized laboratory germination tests.
2. Determine the variability in germination response among collection locations.
3. Monitor changes in germinability over time.
4. Determine the variability in germination response as a function of plant size.

5. Determine the interactive effects of temperature and water potential on germination response.
6. Outline potential objectives for future research.

Materials and Methods

T. repandum seeds were collected in August 1991 from seven sites on the Challis National Forest and BLM Salmon District lands in east-central Idaho. Collection sites were located at Road Creek (RC), Herd Creek (HC), Lime Creek (LC), Main Bayhorse (MB), Dry Gulch (DG), Spar Canyon (SC) and Bayhorse Road (BR). Seeds were obtained from 15 individual plants at each location (14 from SC). Individual plants were classified as to relative size varying from x-small to xx-large. Total seed number from each plant was estimated by multiplying the number/weight ratio of a subsample by the total weight of collected seeds. Seed numbers collected from individual plants ranged from 5 to approximately 3000. Table 1 gives the approximate seed numbers collected from individual plants and their relative size classification by location.

Experiment 1 - Germination Response to Temperature as a Function of Location

Seeds from individual plants were combined to obtain an aggregate sample from each collection location. The first germination test for these seeds was initiated in January, 1992. Seed germination response was determined at 5, 10, 15, 20, 25, 30 and 35 °C for six replicate samples of 35 seeds from each location. Seeds were germinated on cellulose membrane in a germination cup designed for control of matric potential in the seed germination environment. This system is described in detail by Hardegree and Emmerich (1992). Germination vials were maintained inside a series of controlled environment chambers which were programmed to maintain the appropriate temperature to within 1 °C. Seeds were germinated under fluorescent lights which were on for 12 hours/day. Germination vials were opened and checked for germinated seeds on days 1-5, 7, 9, 11, 14, 17 and 21. Seeds were considered germinated and were counted and removed when they exhibited radicle extension of $\geq$ 2mm. Seeds were treated with a fungicide suspension (Daconil; 2.5g/100ml H_2O) on the first day and upon any subsequent day that fungal growth appeared.

A second germination test was initiated in August, 1992, however, there were insufficient seed numbers to duplicate the first experimental run. Measurement of germination response in the second test were limited to only 4 replicate samples at each temperature, and did not include seeds from the SC and BR sites.

For this and subsequent experiments, two germination indices were calculated for the seeds from each germination vial: total percent germination (G), and days to reach 50% of G (D_{50}) as an index of germination rate.

Experiment 2 - The Effect of Relative Plant Size on Total Germination and Germination Rate.

Every source plant that produced more than 30 seeds was tested for individual germination response at 25 °C. Up to 6 replicate samples per plant were tested depending upon availability of seed. Experimental protocol followed that used in Experiment 1 except only one temperature was evaluated. Table 1 gives the distribution of individual plants among locations as partitioned by relative plant size. This experiment was initiated in February, 1992, shortly after completion of Experiment 1.

Experiment 3 - Effects of Temperature and Water Potential on Germination Response

After Experiment 2, all remaining seeds were aggregated by location. Twenty percent by weight of the seed from each location were then aggregated for a determination of interactive temperature and water potential effects on germination response. PEG was mixed with water to yield solutions of 0, -0.1, -0.4, -0.7, -1.0, -1.3 and -1.6 MPa according to equation 4 of Michel (1983) as suggested by Hardegree and Emmerich (1990). PEG solution water potential varies with temperature so a different set of solutions was mixed for each of the temperature treatments. Four replicate samples of 35 seeds each were evaluated for germination response at each combination of temperature and water potential. Seeds were checked every day for 21 days and removed when they exhibited radicle extension of ≥ 2 mm.

Results

There was considerable variation in G among locations but the general pattern of temperature response was consistent (Table 2). In the first germination test, maximum values of G generally occurred between 25 and 30 °C (Table 2, Fig. 1). In the second germination test, optimal temperature for total germination response was more well defined at 30 °C (Table 2, Fig. 1). Total percent germination was significantly higher at 25 and 30 °C during the second test run (Table 2, Fig. 1).

Germination rate response to temperature was more consistent among locations (Table 3). Maximum germination rate, was generally found to occur between 20 and 25 °C for both experimental runs (Table 3, Fig. 2). Germination rate was generally lower (D_{50} higher) during the second test run especially for the intermediate temperatures (Table 3, Fig. 2).

One objective of the Experiment 1 was to determine standard temperature conditions for Experiment 2 and subsequent experiments. The first run of Experiment 1 indicated that the overall optimal temperature for both total percent germination and germination rate occurred at about 25 °C. Total percent germination increased significantly during the second run of Experiment 1 at 30 °C but the optimal temperature for germination rate stayed about the same.

There was high variability in germination response among individual plants and among collection locations but no apparent relationship between relative plant size and either total percent germination or germination rate (Figs. 3-6). The figures show data from all collection locations by relative size class. As seed collections were made by different people, we recognized that the relative sizes are consistent only in relation to other size classes from the same collection location. Within a given location, however, there were also no consistent patterns among relative size classes.

Some germination of *T. repandum* occurred at all of the test temperatures but over a relatively limited water potential range (Tables 4-5, Figs. 7-8). Experiment 3 was run simultaneously with the second run of Experiment 1 and again shows peak total percent germination to have occurred around 30 °C (Fig. 7). Peak germination rate, however, appeared to shift toward a higher temperature as water potential became more negative (Fig. 8).

Discussion

The main purpose of this study was to provide some baseline data on the germination dynamics of *T. repandum*. The first objective was to determine a standard temperature for seed source evaluation in subsequent experiments. Our data show that total percent germination and germination rate respond differently to temperature. We suggest that future standardized tests be carried out over the temperature range of 20 to 35 °C rather than at a single temperature of 25 °C.

There was considerable variability in germination response among collection locations but specific site effects cannot be determined since we have data from only a single year. There is also considerable variability in germinability among individual plants. There does not appear to be any relationship, however, between relative plant size and either total percent germination or germination rate. Future seed collections can be aggregated by collection location without further consideration of specific plant origin.

Total percent germination increased significantly between test runs of Experiment 1 which suggests a possible after-ripening requirement. Low initial germinability may be an advantage for this species since optimal conditions for successful establishment probably do not occur until the following spring. No reproducing individuals were observed during 1992 which indicates that seed remain viable in the soil for at least two years. Our data show that most of the seeds remained dormant after one year but that germinability increases with time. We will continue to monitor the seeds from the five remaining collection locations to determine whether this trend continues.

The data for interactive temperature and water potential effects indicate that this species may have a restricted range of environmental conditions over which it can successfully reproduce. Considering the macro-climatic regime of east-central Idaho, this species requires fairly high temperatures for germination. Barren, dark soils characteristic of *T. repandum* habitat, however, can be expected to absorb heat and produce relatively warm micro-climatic conditions necessary for germination. The relatively wet conditions required for germination also fits in well with described soil conditions of *T. repandum* habitat. Almost all of the water retained in coarse soils occurs in the very high water potential range. The temperature and water potential response of *T. repandum* seeds may, therefore, indicate specific adaptation to the seedbed microclimatic conditions specific to their habitat.

These experiments are limited in their applicability because of the artificial nature of the laboratory test environment. We have tentatively confirmed, however, that germinability of *T. repandum* seeds increases over time and that the seeds have a relatively restricted range of conditions over which they will germinate. I would like to suggest that the next round of experiments be designed to test hypotheses related to these two observations. We now have the capability for continuously-variable temperature control in seed germination studies. The ARS-NWRC is also developing techniques for characterizing seedbed microclimate as a function of soil and macroclimatic site conditions. I suggest that in the next year we evaluate *T. repandum* site conditions and try to simulate field temperature regimes in the laboratory. We should also design a more comprehensive study to determine after-ripening effects on *T. repandum* germinability.

References

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Hardegree, S.P. and W.E. Emmerich. 1992. Effect of matric-priming duration and priming water potential on germination of four grasses. Journal of Experimental Botany 43:233-238.

Michel, B.E. 1983. Evaluation of the water potentials of solutions of polyethylene glycol 8000 both in the presence and absence of other solutes. Plant Physiology 72:66-70.

TABLE 1 - Approximate seed numbers and relative size classification by individual plant and collection site for *Thelypodium repandum* collected in August, 1991 near Challis, Idaho.

	Relative Size Class							
Location	XS	S	SM	M	ML	L	XL	XXL
Road Creek	100	100		90		400		
8-13-91	600	700		125		200		
	100	150		125		700		
	40			450				
				50				
Dry Gulch		30		200		300		
8-6-91		100		125		200		
		50		150		500		
				200		300		
				300		75		
						200		
						400		
Lime Creek		100		100		3000		2000
8-2-91				100		700		900
						125		450
						1700		700
						125		
						125		
						700		
						800		
Main Bayhorse				125		240	600	
8-13-91				450		50	30	
						70	550	
						120	25	
						80		
						50		
						100		
						60		
						225		
Herd Creek		175		275		250	600	
8-6-91		200		110		125	225	
						350	450	
						150	350	
							800	
							575	
							475	
Spar Canyon		50		25		50	200	75
8-13-91						175	225	
						10	50	
						30		
						125		
						30		
						40		
						5		
Bayhorse Road		250	25	200	30	30		
8-8-91		25	200	250	50	275		
		75	75	375				
		50		60				
Total/class	840	2055	300	3885	80	13190	5155	4125
Total 29630								

Table 2 - Mean values for total percent germination (G) as a function of temperature for seeds aggregated by collection location. Test numbers refer to the first germination test in January, 1992 and the second germination test in August, 1993. Standard errors are in parentheses.

Location - test	Temperature						
	5	10	15	20	25	30	35
RC-1	1.1(1.5)	4.0(2.3)	6.3(3.4)	5.0(4.6)	9.0(4.7)	10.0(5.7)	4.0(3.7)
RC-2	0.8(1.4)	5.0(2.1)	3.8(4.0)	7.0(2.7)	17.3(3.0)	25.6(5.4)	5.0(1.5)
DG-1	1.1(1.5)	6.3(6.7)	6.2(4.5)	2.8(2.3)	10.3(3.8)	12.4(7.4)	4.0(2.3)
DG-2	0.7(1.2)	3.1(4.0)	3.4(3.4)	4.2(1.9)	20.6(4.7)	55.2(11.3)	6.1(2.1)
LC-1	5.1(3.4)	13.5(5.3)	15.1(7.7)	22.4(3.5)	20.7(7.5)	22.3(1.7)	8.7(7.9)
LC-2	2.2(2.4)	8.2(4.3)	16.0(10.4)	17.8(6.4)	34.6(6.7)	53.1(9.7)	8.3(5.5)
MB-1	0.6(1.2)	7.3(4.6)	11.3(3.1)	11.7(5.0)	16.2(7.2)	17.9(6.8)	3.9(1.2)
MB-2	0.7(1.3)	3.1(3.8)	9.1(3.7)	10.0(3.4)	25.9(3.5)	29.5(8.9)	3.7(2.4)
HC-1	1.1(2.5)	5.6(3.2)	8.7(3.5)	9.0(4.2)	9.8(6.4)	4.5(4.6)	0.6(1.2)
HC-2	0.8(1.4)	3.7(2.5)	2.6(2.7)	5.1(4.4)	18.4(2.6)	25.2(10.8)	1.5(1.5)
SC-1	0.6(1.2)	10.6(3.5)	14.4(7.1)	21.1(3.7)	22.1(5.2)	21.6(7.2)	4.1(6.6)
BR-1	1.7(2.5)	5.2(2.7)	5.9(6.0)	7.8(3.1)	10.7(4.5)	13.4(5.4)	13.1(7.5)
all-1	1.6(1.5)	7.5(3.1)	9.8(3.6)	11.4(7.1)	14.1(5.1)	14.6(6.0)	5.5(3.8)
all-2[1]	1.1(0.6)	4.6(1.9)	7.0(5.1)	8.8(4.9)	23.4(6.3)	37.7(13.5)	5.0(2.4)

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[1] These values represent the mean of only the five locations measured in the second germination test.

Table 3 - Mean values for days to 50% of G (D50) as a function of temperature for seeds aggregated by collection location. Test numbers refer to the first germination test in January, 1992 and the second germination test in August, 1993. Standard errors are in parentheses.

Location - test	Temperature						
	5	10	15	20	25	30	35
RC-1	19.0(0)	11.2(2.7)	6.1(1.2)	4.4(1.0)	4.3(2.1)	6.5(3.2)	6.6(2.6)
RC-2	12.5(0)	17.9(1.4)	9.6(3.6)	7.0(1.7)	5.1(1.2)	10.6(0.3)	5.6(1.9)
DG-1	19.0(0)	9.7(2.3)	5.1(1.5)	4.6(1.9)	3.2(0.6)	6.4(3.0)	9.3(6.6)
DG-2	19.0(0)	10.3(0.3)	5.5(1.5)	4.5(0.9)	6.9(2.4)	10.0(0.9)	9.1(3.1)
LC-1	16.9(1.7)	9.8(2.6)	5.1(0.7)	3.2(0.3)	2.8(0.2)	3.5(0.3)	3.3(2.2)
LC-2	16.5(2.5)	11.2(1.0)	7.1(1.5)	5.9(3.4)	3.8(0.2)	7.0(1.0)	12.0(4.3)
MB-1	19.0(0)	9.7(1.2)	6.7(0.9)	4.8(1.5)	3.8(0.6)	6.6(2.1)	6.3(4.7)
MB-2	19.0(0)	14.0(4.0)	8.1(1.7)	7.4(1.8)	4.7(0.9)	5.5(1.1)	6.2(2.8)
HC-1	15.5(0)	10.1(0.7)	5.7(3.2)	3.8(0.6)	4.5(1.1)	5.4(1.3)	3.5(0)
HC-2	19.0(0)	14.7(3.3)	5.3(1.3)	5.2(1.4)	5.6(2.3)	12.5(3.9)	9.3(3.3)
SC-1	19.0(0)	11.3(2.6)	7.2(2.5)	6.6(0.8)	6.0(2.2)	6.4(1.6)	12.9(1.9)
BR-1	19.0(0)	11.4(3.5)	5.1(1.2)	4.0(1.0)	2.8(0.3)	4.2(1.1)	11.1(4.4)
all-1	18.2(1.3)	10.5(0.8)	5.8(0.8)	4.5(1.0)	3.9(1.0)	5.6(1.2)	8.4(2.9)
all-2[1]	17.2(2.5)	13.6(2.7)	7.2(1.5)	6.0(1.1)	5.2(1.0)	9.1(2.5)	8.4(2.2)

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[1] These values represent the mean of only the five locations measured in the second germination test.

Table 4 - Mean values for total percent germination (G) as a function of temperature and water potential for seeds aggregated accross all collection locations. Standard errors are in parentheses.

Water Potential (MPa)	Temperature 5	10	15	20	25	30	35
0	3.7(1.2)	5.0(3.1)	10.3(5.5)	14.6(4.6)	32.8(7.5)	41.0(8.2)	13.1(2.3)
0.1		3.1(2.3)	4.3(3.2)	12.0(5.3)	22.0(3.1)	34.8(5.0)	4.4(4.4)
0.4		1.5(2.6)	8.9(4.2)	6.6(3.7)	12.9(7.5)	17.3(12.8)	1.4(1.4)
0.7			3.2(2.5)	5.8(4.3)	7.8(2.1)	4.6(1.3)	1.6(2.7)
1.0						4.0(5.3)	

Table 5 - Mean values for days to 50% of G (D50) as a function of temperature and water potential for seeds aggregated accross all collection locations. Standard errors are in parentheses.

Water Potential (MPa)	Temperature 5	10	15	20	25	30	35
0	19.1(1.4)	12.2(1.6)	8.0(3.8)	3.9(0.1)	3.9(0.5)	7.5(2.8)	10.9(2.8)
0.1		14.2(3.9)	11.7(4.4)	6.7(3.8)	4.7(0.7)	10.3(4.9)	14.0(6.4)
0.4		18.0(0.0)	10.8(3.0)	8.8(2.4)	4.9(1.3)	8.5(3.4)	13.0(1.5)
0.7			13.0(2.5)	13.8(2.7)	10.9(2.9)	7.5(2.4)	10.0(0.0)
1.0						11.1(6.6)	

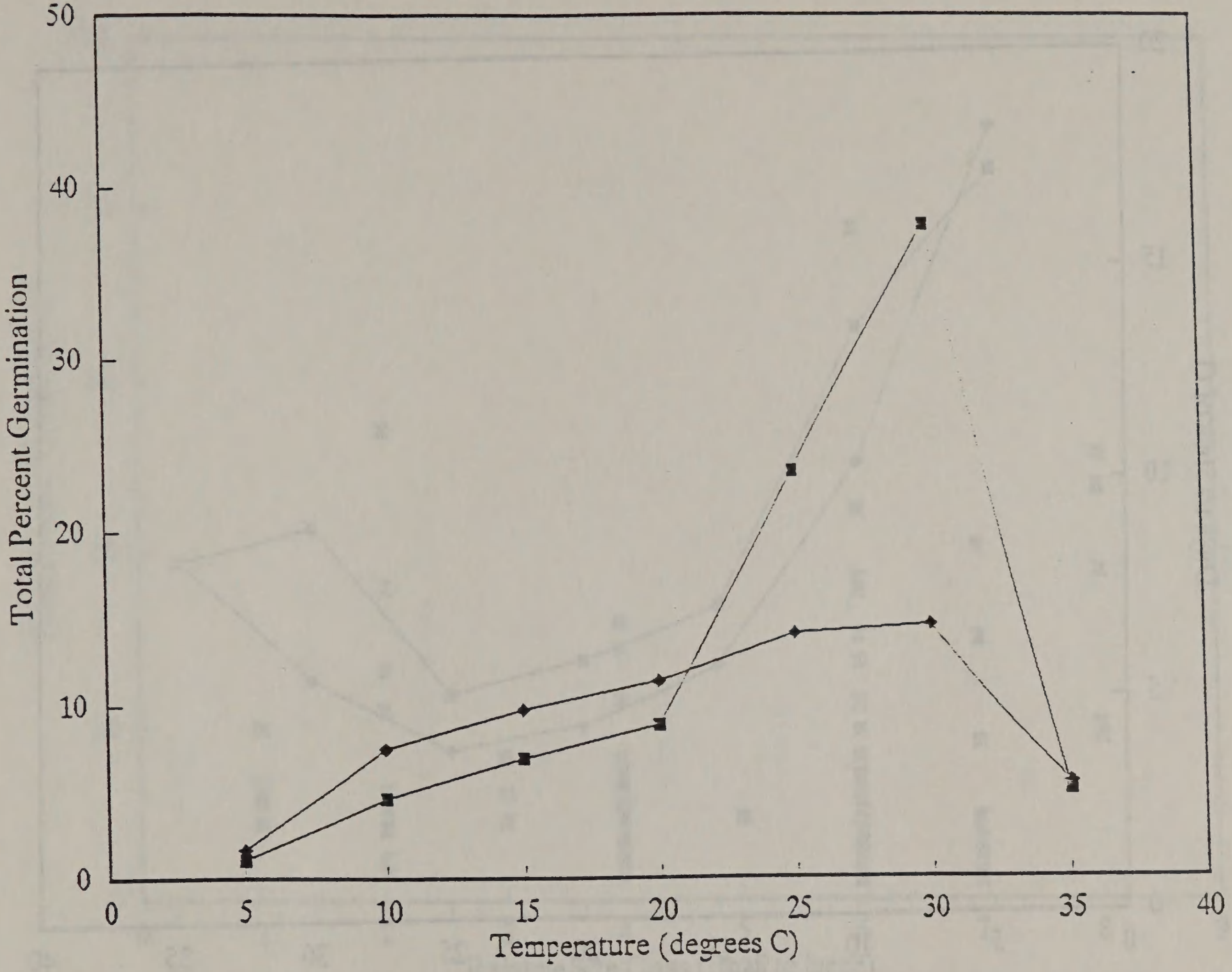

Figure 1 - Total percent germination (G) as a function of temperature for germination tests initiated in January, 1992 (◆) and August, 1992 (■).

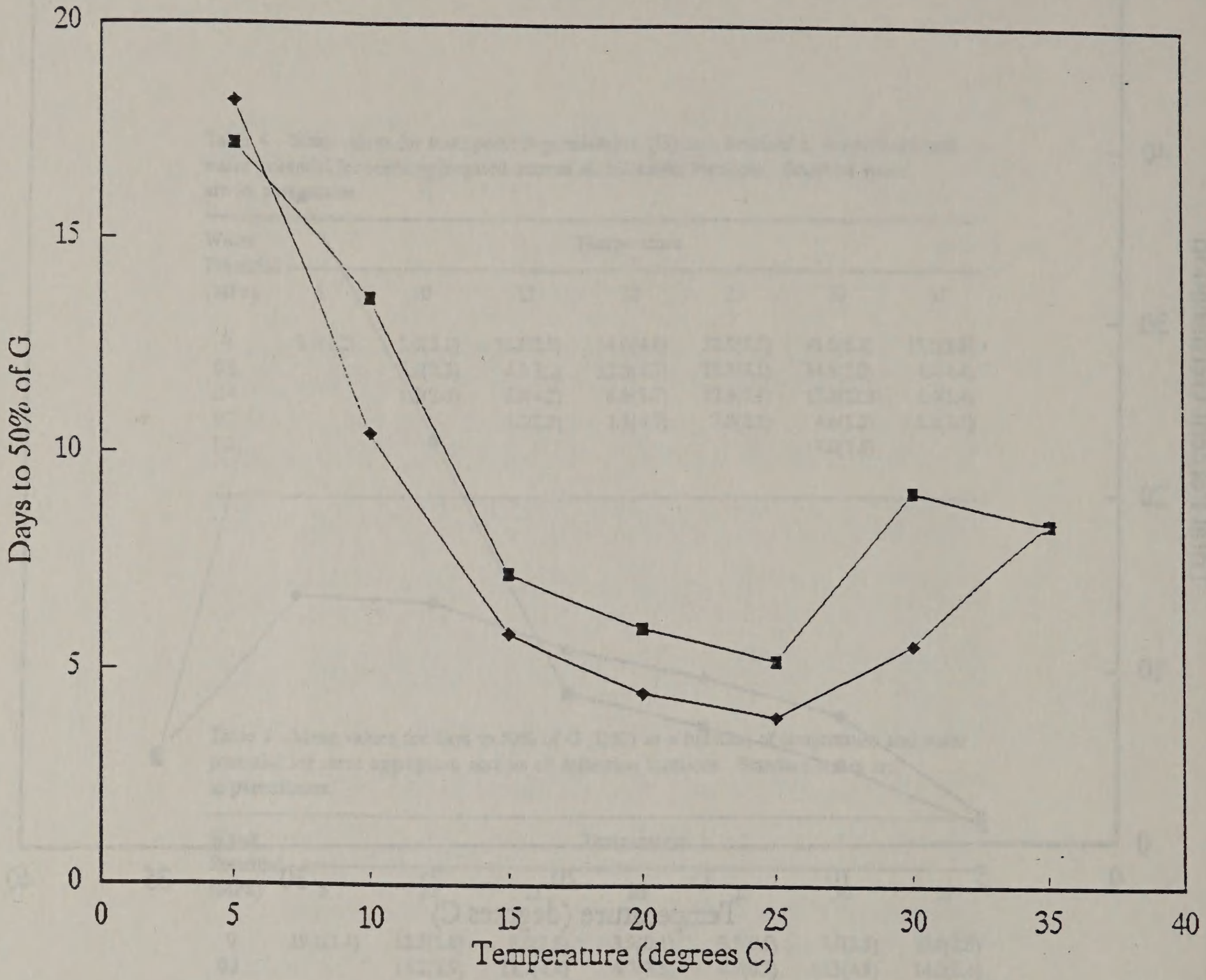

Figure 2 - Days to 50% of G (D_{50}) as a function of temperature for germination tests initiated in January, 1992 (◆) and August, 1992 (■).

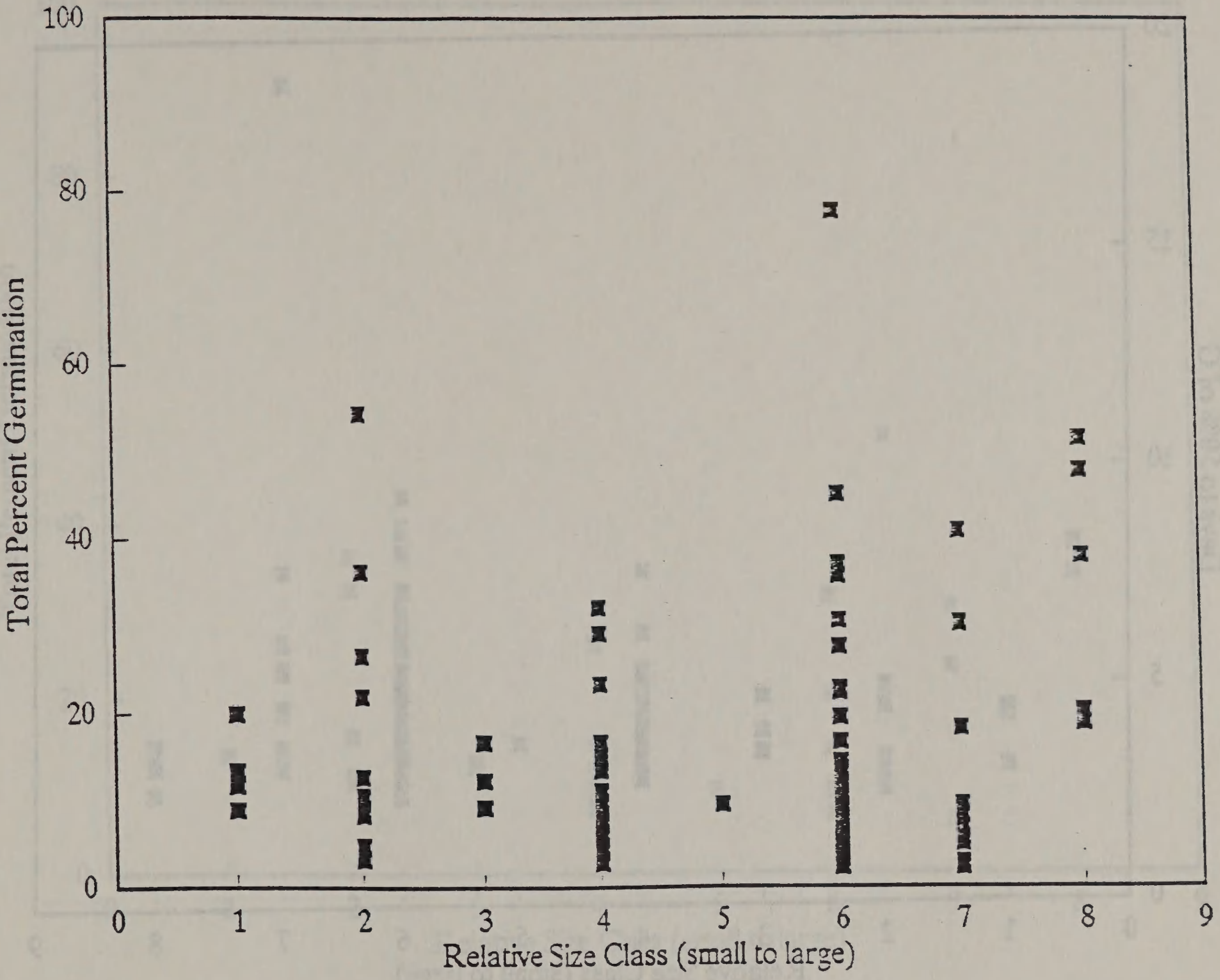

Figure 3 - Total percent germination (G) as a function of relative size class for individual plants from all collection locations. Relative size classes correspond to the range of X-SMALL to XX-Large from Table 1.

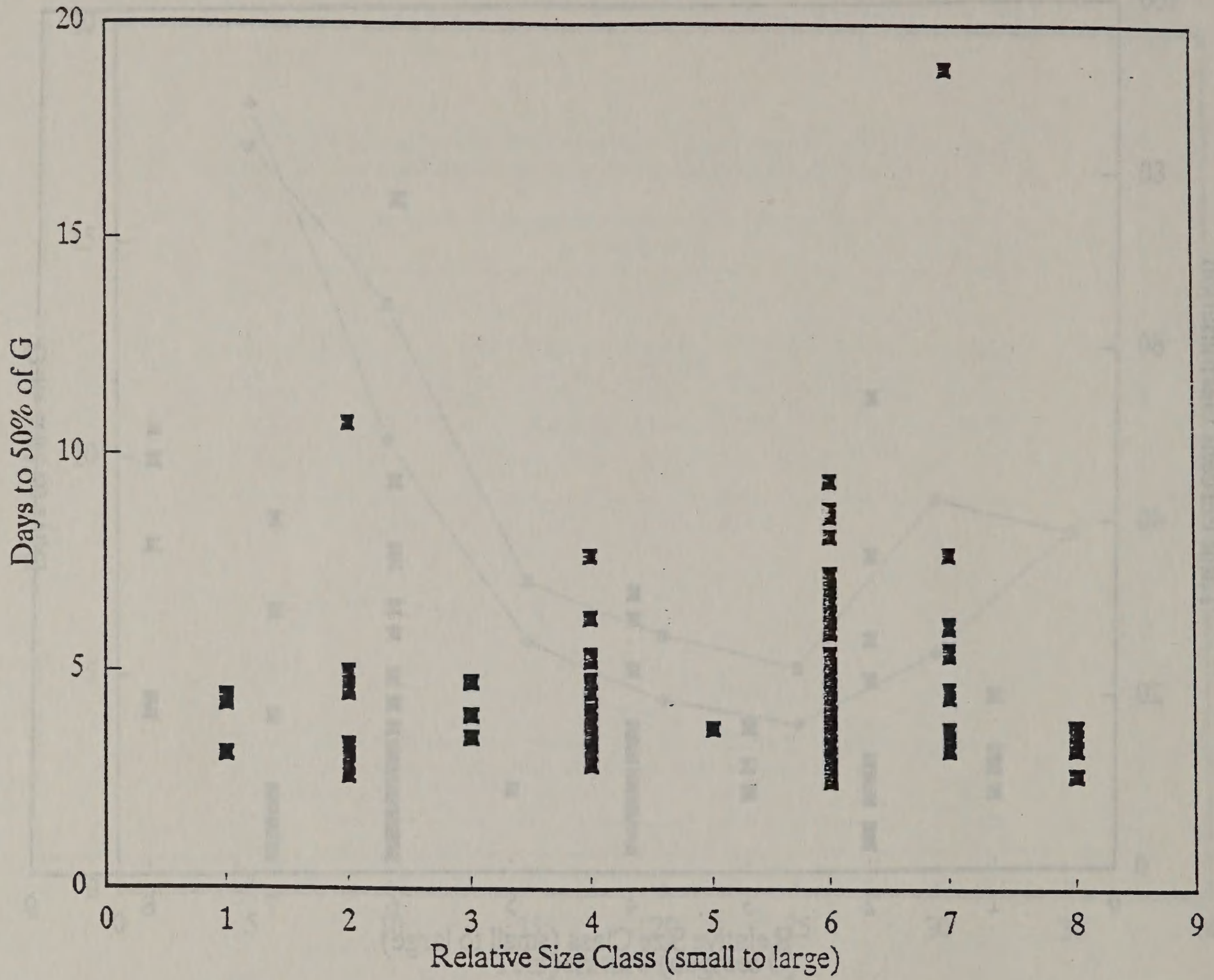

Figure 4 - Days to 50% of G (D_{50}) as a function of relative size class for individual plants from all collection locations. Relative size classes correspond to the range of X-SMALL to XX-Large from Table 1.

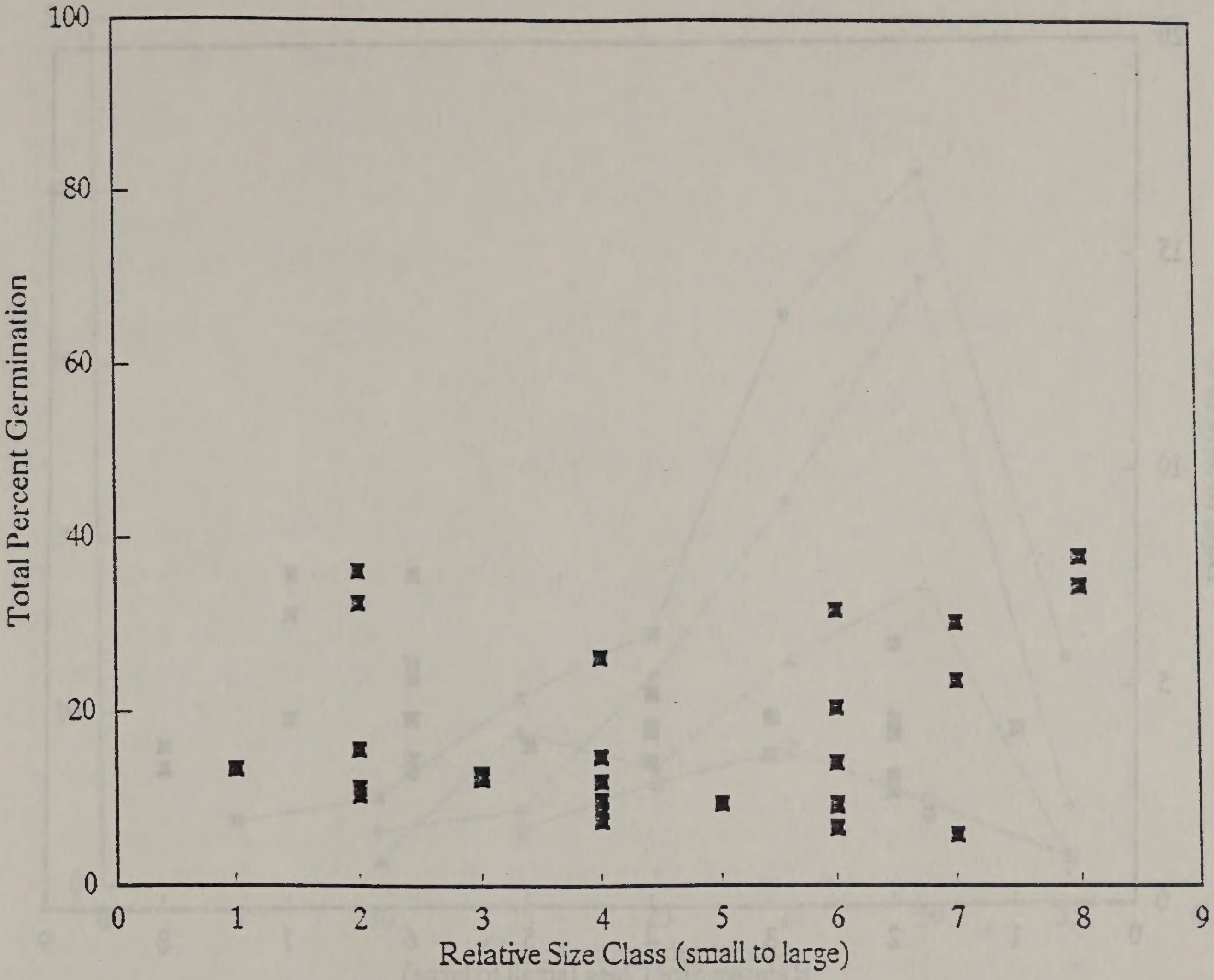

Figure 5 - Total percent germination (G) as a function of relative size class for seeds averaged within collection locations. Relative size classes correspond to the range of X-SMALL to XX-Large from Table 1.

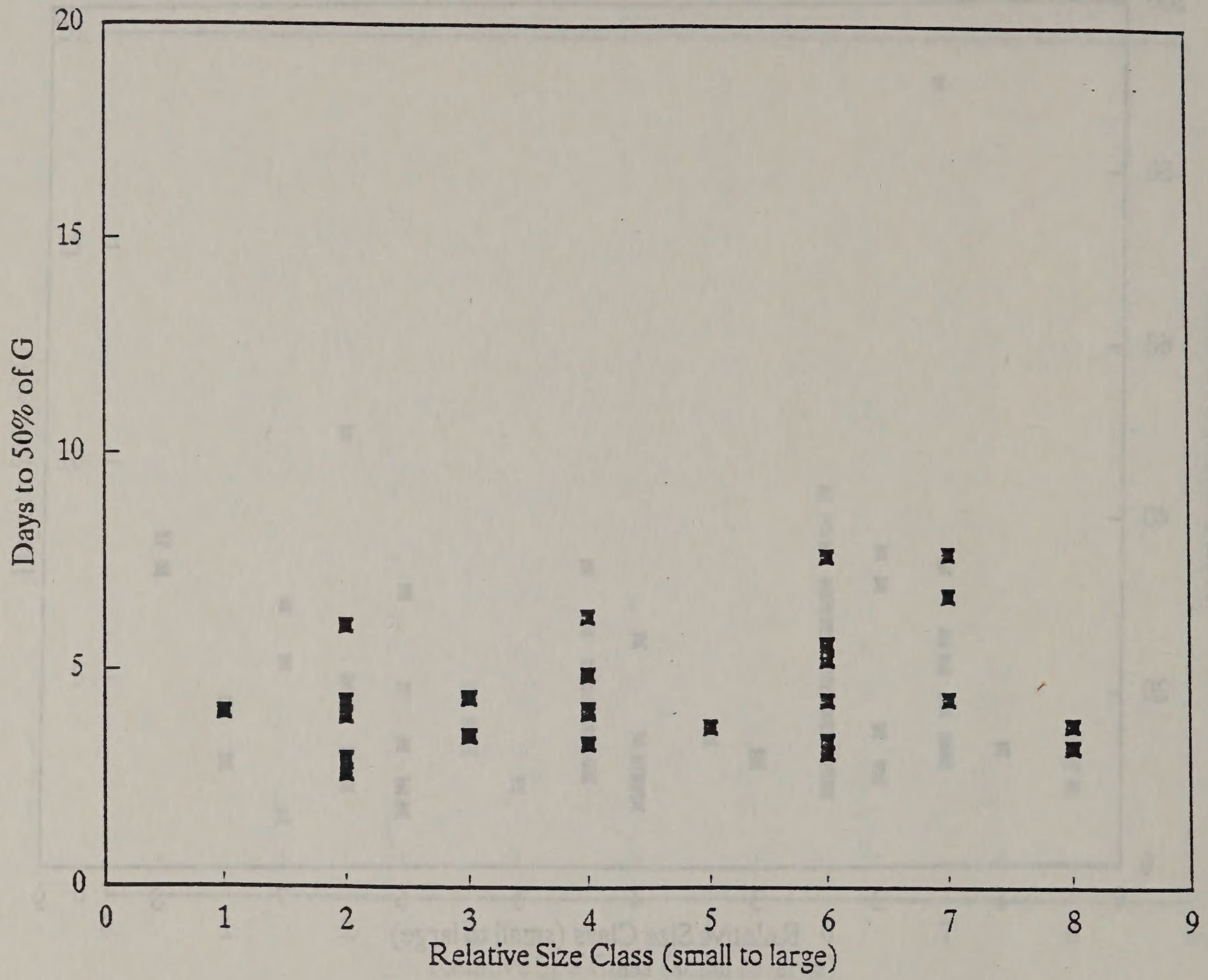

Figure 6 - Days to 50% of G (D_{50}) as a function of relative size class for seeds averaged within collection locations. Relative size classes correspond to the range of X-SMALL to XX-Large from Table 1.

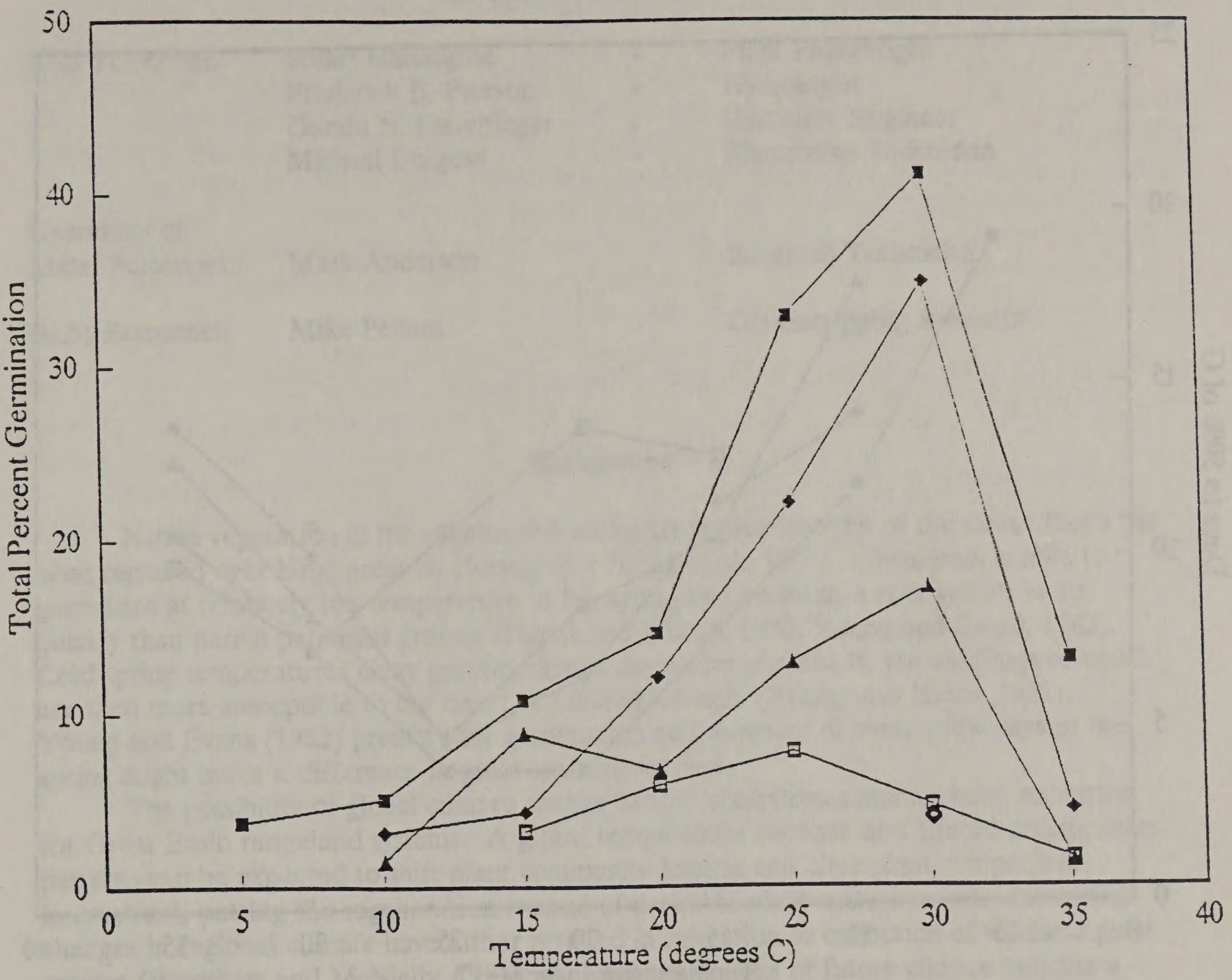

Figure 7 - Total percent germination (G) as a function of temperature at 0 (■), -0.1 (◆), -0.4 (▲), -0.7 (□), and -1.0 MPa (◇) for seeds aggregated across all collection locations and germinated in August, 1992.

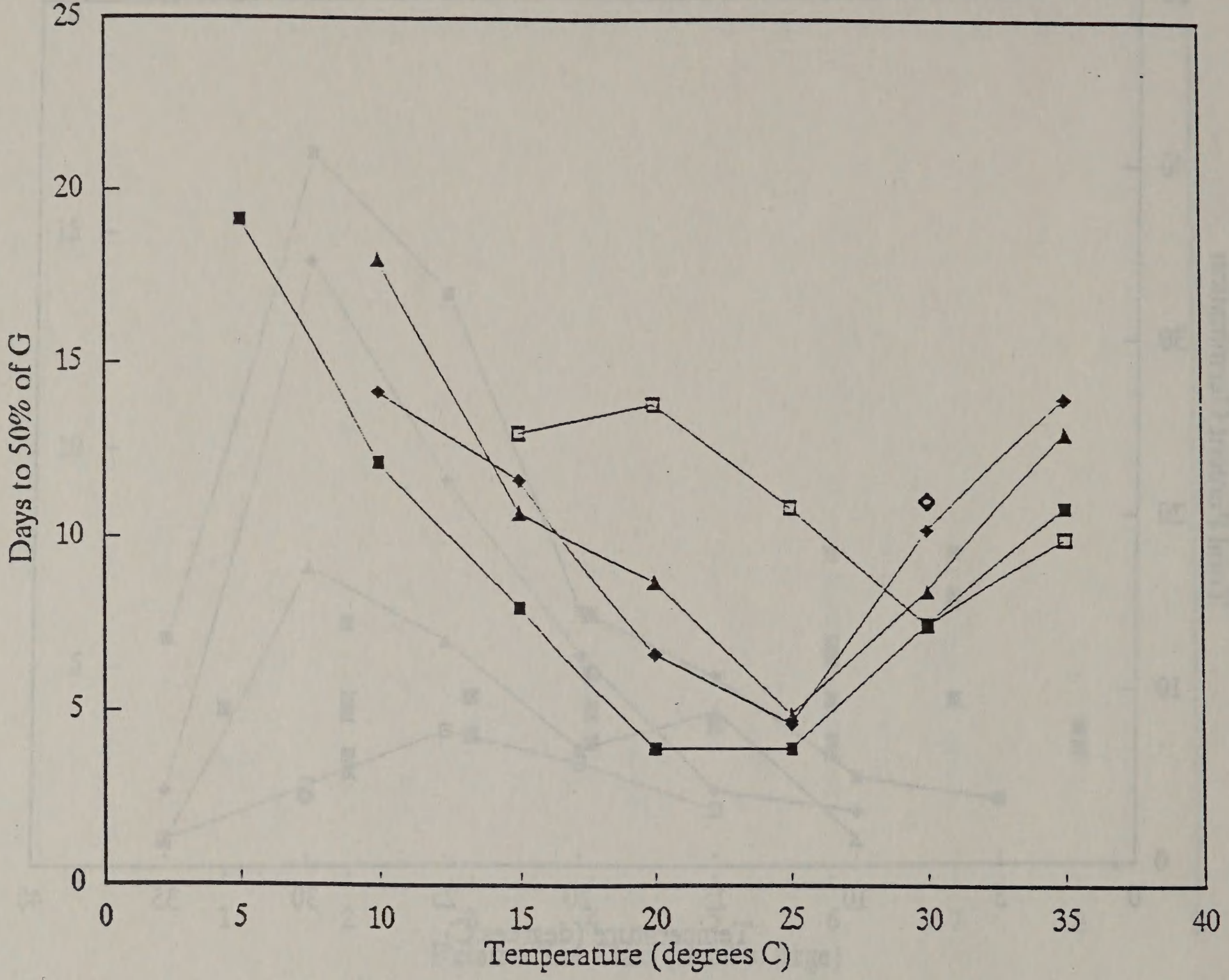

Figure 8 - Days to 50% of G (D_{50}) as a function of temperature at 0 (■), -0.1 (◆), -0.4 (▲), -0.7 (□), and -1.0 MPa (◇) for seeds aggregated across all collection locations and germinated in August, 1992.

3. GERMINATION ENHANCEMENT OF NATIVE GRASSES FOR RESTORATION OF DETERIORATED RANGELANDS IN THE GREAT BASIN

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Background

Native vegetation in the sagebrush/bunchgrass vegetation type of the Great Basin has been replaced over large areas by cheatgrass (Young et al., 1987). Cheatgrass is able to germinate at relatively low temperature in the spring and establish a root system more quickly than native perennial grasses (Harris and Wilson, 1970; Young and Evans, 1982). Cold spring temperatures delay germination of the native perennials, the seedlings of which are then more susceptible to the onset of summer drought (Young and Evans, 1982). Young and Evans (1982) predict that germination advancement of even a few days in the spring might make a difference in grass seedling survival.

The possibility of global climate change further complicates management scenarios for Great Basin rangeland systems. A global temperature increase and altered precipitation patterns can be expected to shift plant community habitat and alter plant competitive interactions, putting the regeneration success of desirable plant species at risk. Historical changes in regional climate have either resulted in migration or extinction of wildland plant species (Bradshaw and McNielly, 1991). Current predictions of future climate indicate a much faster rate of change than would normally occur in the absence of human influences. Rapid change may, therefore, limit natural species migration and adversely affect plant productivity and native plant diversity (Huntley, 1991). New technologies will have to be developed to mitigate potentially undesirable effects of global change on rangeland ecosystems.

Objectives

The objective of this research is to enhance our ability to successfully establish native plants in areas infested with cheatgrass. This objective can be partitioned into four sub-objectives: 1) Laboratory development of seed treatments to enhance low temperature germination rate of native grass species; 2) Field and laboratory determination of seedbed microclimatic conditions limiting germination response; 3) Enhancement and validation of process models for predicting heat and water flux in the seedbed; and 4) Development of predictive technology for optimizing planting strategies for spring establishment of native plant species.

Current Status

Sub-Objective 1 - Germination Rate Enhancement of Native Grasses

During fiscal year 1992, two laboratory germination studies were completed and a third study initiated under this sub-objective. The following species were used in these experiments: bluebunch wheatgrass (*Pseudoroegneria spicata*), thickspike wheatgrass (*Agropyron dasystachyum*), basin wildrye (*Leymus cinereus*), Sandberg bluegrass (*Poa sanbergii*), bottlebrush squirreltail (*Sitanion hystrix*), sheep fescue (*Festuca ovina*), and canby bluegrass (*Poa canbyi*). Germination response of these native species was compared to that of cheatgrass (*Bromus tectorum*) which was collected in 1991 from three sites in southern Ada County near Kuna Butte, Tenmile Creek and Orchard Idaho.

Experiment 1 - Initial Characterization of Matric-Priming Effects on Great Basin Native Perennial Grasses

Seed priming is a presowing seed treatment that has been shown to enhance germination rate at sub-optimal temperatures (Heydecker et al., 1975). Seeds can be induced to germinate rapidly by first equilibrating them at a water potential that allows imbibition but prevents radicle emergence (Heydecker and Coolbear, 1977). The magnitude of the effect depends upon the priming medium, priming conditions of water potential, duration and temperature, and whether the seeds are redried after priming (Bradford, 1986; Heydecker, 1977; Heydecker and Coolbear, 1977). The purpose of this experiment was to determine whether priming could be used to improve the cold temperature germination rate of seven Great Basin native perennial grasses. Specific objectives were to: determine the effects of priming temperature and priming duration on total germination and germination rate; and to compare low-temperature germination rates of primed and non-primed native grass seeds to cheatgrass.

Methods

Seeds were primed and germinated in special vials designed for control of matric-potential in the seed germination environment (Hardegree and Emmerich, 1992). A preliminary experiment was conducted to determine the optimal priming-water potential for each species. As a first approximation, the optimal priming water potential was determined to be the least negative water potential that did not result in radicle extension during a two week germination test. Seeds were primed for either 2, 4, 6, or 8 days at both 10 and 25 °C. Germination response after priming was also evaluated at both 10 and 25 °C. A set of non-primed control treatments was initiated at the same time that primed seeds were transferred to germination vials containing pure water. These control treatments included the three cheatgrass seed lots collected during the same year as the germination study. Each treatment combination of species, priming-duration, priming-temperature and germination-temperature was replicated 5 times. Non-primed control treatments of all native species and cheatgrass were replicated 10 times.

Two germination indices were calculated for each replicate sample: total percent germination (G); and days required to reach 50% of G (D_{50}) as an index of germination rate. Mean values and confidence limits ($P \leq 0.05$) for the control treatments were determined for each combination of germination index, species and germination-temperature. Quadratic regression equations were calculated to relate G and D_{50} to priming duration for each species at each combination of priming-temperature and germination-temperature (Evans et al., 1982). Germination index values were estimated from the regression equations and model confidence intervals ($P \leq 0.05$) determined for each treatment combination of species, priming-temperature, germination-temperature and priming-duration (Evans et al., 1982). Priming was considered to have had a significant effect on germination if the modeled confidence interval for a given treatment did not overlap the mean value for the non-primed control treatment. Control treatments (which had a priming-duration of 0 days) were not included in the regression analysis.

Results

Priming had either a positive effect or no effect on G for all species and treatments except for sheep fescue seeds germinated at 10 ° C (Table 1). There was no consistent pattern of priming-temperature and priming-duration effects on G but canby bluegrass was the only species for which G was unaffected by any treatment (Table 1).

Priming increased germination rate (decreased D_{50}) relative to the controls for almost every combination of priming-temperature and priming-duration (Table 2). The only exceptions were for two treatments of bluebunch wheatgrass and one of basin wildrye which could not be distinguished from control values (Table 2). In all cases, the effect of priming on germination rate was relatively greater for seeds germinated at 10 ° C (Table 2).

For the majority of species and treatments the germination rate increase was greater for seeds that had been primed at 25 ° C (Table 2). This pattern was reversed for basin wildrye which generally had faster germination when primed at 10 ° C (Table 2). For the other species, lower priming temperatures were associated with more rapid germination only in longer duration treatments (Table 2). In general, increasing priming duration tended to lower D_{50} values. This trend either continued over the 8 day treatment range or started to reverse in the longer duration treatments (Table 2).

Native grass seeds in the control treatments took between about 4 and 11 days longer to germinate at 10 ° C than did the cheatgrass accessions (Table 2). Priming advanced germination by up to 8.5 days for bottlebrush squirreltail but only three species (bluebunch wheatgrass, thickspike wheatgrass and sheep fescue) had priming treatments that lowered D_{50} to levels comparable to cheatgrass when germination was evaluated at 10 ° C (Table 2).

Discussion

Matric-priming increased germination rate of all species at both 10 and 25 ° C (Table 2). Results from this experiment are consistent with previous priming studies that have shown a relatively greater germination rate increase for seeds germinated at temperatures normally sub-optimal for germination (Heydecker et al., 1975; Brocklehurst et al., 1984; Bodsworth and Bewley, 1981; Ali et al., 1990; Szafirowska et al., 1981; Knypl and Khan, 1981). The results of this study are also consistent with those reported by Heydecker and Coolbear (1977) that germination rates can be greater for seeds primed at relatively higher temperature (Table 2).

Priming increased germination rate at 10 ° C for all species but only three species could be induced to germinate at a rate comparable to the cheatgrass accessions (Table 2).

This study was not designed to evaluate within- or between-species variability in germination, therefore, the significance of individual species response cannot be assessed. A strict comparison of native species to cheatgrass is also limited to the specific seedlots used in this study. The data do support some general conclusions, however. All species revealed at least one priming treatment combination that resulted in germination advancement of more than 3.5 days at 10 °C (Table 2). Young and Evans (1982) predicted that germination advancement of even a few days could make a difference in establishment success of cool season perennial grass species. Treatment conditions in this experiment were somewhat arbitrary in that germination response was only determined for four combinations of priming-temperature and germination-temperature. Other priming temperatures would probably affect germination differently. These results also do not necessarily reflect seed response in the field where temperature and water availability would vary over the germination period.

Practical application of matric-priming to rangeland seeding operations must take into account several factors not determined in the current experiment. Matric-priming as described by Hardegree and Emmerich (1992) is not practical for treating bulk quantities of seed. Matric-priming, however, is thermodynamically equivalent to simple water addition to subgermination water content (Heydecker and Coolbear, 1977). Matric-priming can be used to determine the optimal priming conditions of temperature and seed-water-content preliminary to bulk priming with simpler gravimetric techniques such as those described by Heydecker and Coolbear (1977) and Gray et al. (1990).

Experiment 2 - Effect of Drying and Storage on Germinability of Primed Seeds

Practical application of seed priming may require that the seeds be redried after treatment. Freshly primed seeds are metabolically active and probably cannot be stored for long periods without significant loss of viability. The purpose of this experiment was to determine the effect of drying and storage on total germination and germination rate of matric-primed seeds.

Methods

A priming treatment of 7 days at 25 °C was estimated from the previous experiment to be optimal for most of the species tested. Sixty-four sets of seeds from each species were primed under these conditions at the estimated optimal priming water potential determined from Experiment 1. Immediately after priming, 9 sets of seeds of each species were switched to a germination vial containing pure water and monitored for germination at 10 °C. The remaining seeds were redried and stored at room temperature. After 7 days another set of seeds were placed in germination vials containing water and monitored for germination at 10 °C. Subsequent germination tests were initiated every 2 weeks for the next 10 weeks. Control treatments of non-primed native seeds and cheatgrass seeds were initiated every time a new set of primed seeds was tested for germination response.

Days to 50% of *G* was calculated for each germination vial as an index of germination rate (D_{50}). Two priming treatments were distinguished for comparison to the control values: seeds that were switched to water for immediate germination; and seeds that were dried and stored for up to 11 weeks.

Results and Discussion

Figs. 1-7 represent germination rate response of control, primed, and primed/dried seeds of the seven species that were tested. Fig. 8 gives the mean germination rate response of the cheatgrass control treatments. In every case, the germination rate of primed seeds was reduced (D_{50} increased) when seeds were redried after priming. The initial loss of the priming effect ranged from about 20% for bluebunch wheatgrass to over 65% for basin wildrye (Figs. 1-7). In most cases, the bulk of the priming effect was retained after redrying. This indicates that priming induced positive metabolic changes in addition to a simple reduction in the lag time for imbibition.

In the previous experiment, only three species could be induced to germinate as rapidly as cheatgrass at 10 °C. In this experiment, bottlebrush squirreltail and Sandberg bluegrass were also induced to germinate as rapidly as cheatgrass. Bluebunch wheatgrass, however, was the only species that could still compete with cheatgrass after the primed seeds were dried back. It should be noted, however, that the priming treatments used in this experiment were not necessarily the optimal priming treatments for these species.

Storage effects on dried seeds varied with species. The priming effect remained fairly stable for four of the species over the entire storage period. Three species exhibited an increase in D_{50} over time but not until at least a month after the initial dry-down.

Experiment 3 - Determination of Optimal Temperature, Water Potential, and Treatment Duration for Matric-Priming of Selected Grasses

Experiments 1 and 2 showed significant advancement of cold-temperature germination rate for all species tested. Previously tested priming treatments, however, were semi-arbitrary with respect to priming-water potential, temperature and duration. Theoretically, any treatment that does not result in radicle extension could be used for seed priming. The set of potential treatments, therefore, includes those that would normally result in germination if the seeds were not redried immediately after priming. The objective of this experiment is to determine the optimal priming conditions for selected species over the temperature range of 5 to 35 °C, the water potential range of 0 to -2.5 MPa, and the treatment duration range of 1 to 10 days. This objective will be achieved in two stages: first, a germination test will be run to determine all temperature, water potential and duration conditions that do not result in radicle extension; and second, the range of potential priming treatments will surveyed for the optimal combination of priming conditions.

Status

The first part of this experiment has been completed for bluebunch wheatgrass, thickspike wheatgrass, bottlebrush squirreltail and Sandberg bluegrass. Figs. 9-15 are examples of the cumulative germination profile for thickspike wheatgrass over the temperature range of 5 to 35 °C and the water potential range 0 to -1.3 Mpa. We have used this information to derive all of the potential priming treatments of less than 10 day duration that do not result in radicle extension. We are currently priming seeds under these conditions to determine the optimal set of temperature, duration and water potential. We expect to complete evaluation of optimal priming conditions for these four species by March, 1993.

Sub-Objective 2 - Microclimatic Conditions Limiting Germination Response

Young and Evans (1982) compiled the germination-temperature profiles of a large number of cool-season range grasses but, because of equipment limitations, could only measure constant-temperature and alternating-constant-temperature response. Rangeland ecosystems, however, are characterized by a high degree of spatial and temporal variability in seedbed microclimate (Pierson and Wight, 1991). Germination response to constant- or alternating-temperature in the laboratory does not adequately reflect germination response in the field. We initiated two experiments during fiscal year 1992 to address this problem.

Experiment 1 - The Effect of Temperature Variability on Seed Germination Response

The USDA-ARS research center in Boise has recently completed construction of a germination-control system that can simulate continuously-variable temperature regimes. This germination system has 15 separate units that are programmable to follow any type variable temperature conditions. Fig. 16 shows the average germination vial temperature on each of four levels in our prototype germinator under a simulated sine-wave temperature pattern. Our objective in this first experiment was to determine the difference in germination response among temperature treatments with the same average temperature but different patterns of temperature variation.

Methods

Each of 15 germinators was programmed to simulate one of the following temperature patterns: 10, 15, 20, 25, 30 and 35 °C constant temperatures; 10/20, 15/25, 20/30 and 25/35 °C alternating temperatures; four sine-wave patterns with the same amplitude and average temperature as the alternating regimes; and one sine-wave pattern with a 10 °C lower limit and a 35 °C upper limit.

Only four species are currently being evaluated for variable-temperature response: bluebunch wheatgrass, thickspike wheatgrass, bottlebrush squirreltail and Sandberg bluegrass. Six replicate samples are being evaluated for each species and temperature regime during each experimental run. Since there are only 15 germinators and 15 separate temperature regimes, this experiment is being run 3 times. After each run, individual temperature regimes are randomly assigned to a different germinator.

Status

We are currently in the middle of the first experimental run. We hope to complete all three runs of this experiment by the middle of February, 1993.

Experiment 2 - Field Temperature Response of Primed and Non-Primed Seeds

Field temperature response of seeds must ultimately be evaluated under natural conditions. Characterization of field microclimate is now relatively easy given current computer technology that permits intensive, continuous monitoring of the temperature and water regime in the seedbed (Evans et al., 1975; Pierson and Wight, 1991; Flerchinger and Pierson, 1991). Field trials of seed germination and emergence, however, are difficult to replicate and must be carried out over several years in order to adequately account for year-to-year variation in microclimate (Hurlbert, 1984). Spatial and temporal variability in the field also limits the usefulness of site-specific data of temperature, moisture and germination response. The purpose of this experiment is to simultaneously measure seed germination response to variable temperature in both the laboratory and the field. The objective is to determine whether laboratory simulations of the germination environment are relevant to predictions of field germination response.

Status

All seedbed monitoring and germination tests are being conducted at the BLM Orchard Field Test Site. The Orchard site is currently being used for revegetation research by the Bureau of Land Management, Soil Conservation Service, US Forest Service, Agricultural Research Service and Boise State University. The Orchard site contains three soil types (loam, silt loam and fine sandy loam) and is currently instrumented with an SCS weather station for monitoring air temperature, wind speed, precipitation, relative humidity and solar radiation.

During fiscal year 1992, three blocks of experimental plots, one in each of three soil types, were instrumented with soil temperature sensors at 1 and 5 cm depths. The central site was also instrumented for hourly measurement of wind speed, relative humidity, air temperature and solar radiation. Sensors are connected to a micro-logger data acquisition system located in each plot. This winter, we will install a separate rain gauge at each of the three sites and a telemetry system for real-time data retrieval of microclimatic variables.

Field trials of primed and non-primed native perennial seeds and cheatgrass germination response will be conducted at the Orchard site starting in March, 1993. These plots were burned in September, 1992 to simulate post fire seedbed conditions. Primed and non-primed native perennial seeds and cheatgrass will be precision planted in three subplots on each soil type at two week intervals and monitored three times per week through spring and early summer. Special plots at the field site are being instrumented with additional thermocouples to monitor temperature at the 1 cm depth. The plots will be irrigated to eliminate water stress effects on germination and emergence. Temperature data will be telemetered to the laboratory and used to program the germinators to simulate the average variable-temperature conditions at 1 cm in each of the three soil types. A simultaneous laboratory germination test using field temperature data will be conducted with a lag time of only 2 days relative to the field experiment.

Sub-Objective 3 - Enhancement and Validation of Seedbed Microclimatic Models

Process-based computer models are currently being developed to predict spatial and temporal variability in seedbed micro-climate (Flerchinger and Pierson, 1991; Pierson and Wight, 1991; Pierson, Flerchinger and Wight. 1992). These models can be used to estimate relevant variable-temperature profiles for laboratory germination tests and as decision aids for prediction of optimal planting scenarios.

Status

Information from the Orchard soil-sensor network will be used in conjunction with climatic data from the on-site weather stations for two purposes: 1) Determination of relevant variable-temperature regimes for laboratory germination experiments; and 2) Validation of computer simulation models for predicting microclimatic variability in the seedbed. The Simultaneous Heat And Water (SHAW) model (Flerchinger and Saxton, 1989; Flerchinger and Pierson, 1991) will be parameterized with soils and weather data from the field site and validated with information from the soil instrumentation. We expect to finish instrumenting the field site with soil temperature and moisture sensors by the end of fiscal year 1993.

Sub-Objective 4 - Development of Predictive Technology for Plant Community Establishment

During fiscal year 1992, ARS scientists met with BLM staff to begin the process of Systems Engineering a program to address problems associated with rangeland restoration, burn rehabilitation and biodiversity maintenance on public rangeland in the intermountain west. We will continue this effort during the next year to coordinate BLM goals and objectives for vegetation management with the research goals of the Boise ARS unit.

Projects to be Undertaken in Fiscal Year 1993

1. Completion of experiments to determine optimal priming conditions for selected grass species.
2. Completion of laboratory experiments to characterize germination response to continuously-variable temperature regimes.
3. Simultaneous laboratory and field evaluation of primed and non-primed seeds under field temperature regimes.
4. Development of bulk-priming treatments for large quantities of seeds.
5. Characterization of soil conditions at the three Orchard field sites for model parameterization.
6. Characterization of climatic conditions at the Orchard field site for model parameterization.
7. Further development of soil sensor technology for model validation at the Orchard field site.

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Table 1. Calculated Total Percent Germination (G) as a function of priming temperature, germination temperature and priming duration. Numbers in parentheses represent one-half confidence interval widths ($P \leq 0.05$). Italicized values were deemed to be significantly different from control treatments.

			Priming Duration (days)				
Species	prim. temp.	germ. temp.	0	2	4	6	8
Pssp	-	10	83(7)				
Pssp	10	10		76(8)	*90(6)*	*91(6)*	*80(8)*
Pssp	25	10		*90(3)*	*90(3)*	*90(3)*	*90(3)*
Pssp	-	25	82(4)				
Pssp	10	25		86(4)	84(3)	82(3)	80(4)
Pssp	25	25		*87(3)*	*87(3)*	*87(3)*	*87(3)*
Sihy	-	10	58(9)				
Sihy	10	10		*69(8)*	*82(6)*	*87(6)*	*84(8)*
Sihy	25	10		*82(3)*	*82(3)*	*82(3)*	*82(3)*
Sihy	-	25	63(7)				
Sihy	10	25		70(7)	70(7)	70(7)	70(7)
Sihy	25	25		*76(6)*	*73(4)*	*69(4)*	65(6)
Poca	-	10	66(15)				
Poca	10	10		71(6)	71(6)	71(6)	71(6)
Poca	25	10		67(6)	67(6)	67(6)	67(6)
Poca	-	25	58(8)				
Poca	10	25		54(7)	63(5)	63(5)	53(7)
Poca	25	25		62(5)	62(5)	62(5)	62(5)
Leci	-	10	49(16)				
Leci	10	10		*72(5)*	*72(5)*	*72(5)*	*72(5)*
Leci	25	10		*71(6)*	*71(6)*	*71(6)*	*71(6)*
Leci	-	25	79(4)				
Leci	10	25		81(4)	81(4)	81(4)	81(4)
Leci	25	25		82(5)	82(5)	82(5)	82(5)
Posa	-	10	60(8)				
Posa	10	10		58(6)	58(6)	58(6)	58(6)
Posa	25	10		61(4)	61(4)	61(4)	61(4)
Posa	-	25	51(8)				
Posa	10	25		*61(4)*	*61(4)*	*61(4)*	*61(4)*
Posa	25	25		57(9)	53(6)	49(6)	45(9)
Feov	-	10	60(4)				
Feov	10	10		*43(4)*	*43(4)*	*43(4)*	*43(4)*
Feov	25	10		*44(9)*	*51(6)*	*51(6)*	*43(9)*
Feov	-	25	42(10)				
Feov	10	25		36(8)	48(6)	52(6)	47(8)
Feov	25	25		43(5)	43(5)	43(5)	43(5)
Agda	-	10	89(6)				
Agda	10	10		91(3)	91(3)	91(3)	91(3)
Agda	25	10		92(3)	92(3)	92(3)	92(3)
Agda	-	25	92(3)				
Agda	10	25		*96(2)*	*96(2)*	*96(2)*	*96(2)*
Agda	25	25		*97(3)*	*95(2)*	92(2)	90(3)
Brte (K)	-	10	80(4)				
Brte (O)	-	10	49(7)				
Brte (T)	-	10	60(7)				
Brte (K)	-	25	80(4)				
Brte (O)	-	25	77(9)				
Brte (T)	-	25	73(6)				

Table 2. Calculated Days to 50% of G (D_{50}) as a function of priming temperature, germination temperature and priming duration. Numbers in parentheses represent one-half confidence interval widths ($P \leq 0.05$). Italicized values were deemed to be significantly different from control treatments.

			Priming Duration (days)				
Species	prim. temp.	germ. temp.	0	2	4	6	8
Pssp	-	10	7.8(1.6)				
Pssp	10	10		8.9(2.3)	7.5(1.5)	*6.0(1.5)*	*4.6(2.3)*
Pssp	25	10		*4.3(0.3)*	*3.9(0.2)*	*3.5(0.2)*	*3.1(0.3)*
Pssp	-	25	2.4(0.2)				
Pssp	10	25		*1.9(0.2)*	*1.9(0.2)*	*1.9(0.2)*	*1.9(0.2)*
Pssp	25	25		*1.6(0.2)*	*1.5(0.1)*	*1.3(0.1)*	*1.2(0.2)*
Sihy	-	10	13.2(1.2)				
Sihy	10	10		*9.4(0.7)*	*7.9(0.5)*	*6.3(0.5)*	*4.7(0.7)*
Sihy	25	10		*7.8(0.9)*	*7.0(0.6)*	*6.2(0.6)*	*5.5(0.9)*
Sihy	-	25	5.9(0.7)				
Sihy	10	25		*4.6(0.4)*	*4.0(0.3)*	*3.4(0.3)*	*2.7(0.4)*
Sihy	25	25		*4.3(0.7)*	*3.2(0.5)*	*2.8(0.5)*	*3.2(0.7)*
Poca	-	10	11.6(1.3)				
Poca	10	10		*9.7(0.7)*	*8.4(0.5)*	*7.0(0.5)*	*5.7(0.7)*
Poca	25	10		*8.7(1.0)*	*7.1(0.8)*	*6.5(0.8)*	*6.9(1.0)*
Poca	-	25	8.1(1.1)				
Poca	10	25		*6.7(0.6)*	*4.9(0.4)*	*3.6(0.4)*	*2.9(0.6)*
Poca	25	25		*4.1(0.3)*	*4.1(0.3)*	*4.1(0.3)*	*4.1(0.3)*
Leci	-	10	14.8(1.8)				
Leci	10	10		*11.0(1.0)*	*11.0(1.0)*	*11.0(1.0)*	*11.0(1.0)*
Leci	25	10		*11.8(1.0)*	*11.8(1.0)*	*11.8(1.0)*	*11.8(1.0)*
Leci	-	25	8.7(0.8)				
Leci	10	25		7.8(1.0)	*5.2(0.8)*	*3.6(0.8)*	*3.1(1.0)*
Leci	25	25		*5.6(0.6)*	*5.6(0.6)*	*5.6(0.6)*	*5.6(0.6)*
Posa	-	10	13.6(0.9)				
Posa	10	10		*11.7(1.1)*	*10.1(0.7)*	*8.5(0.7)*	*7.0(1.1)*
Posa	25	10		*6.1(0.5)*	*6.1(0.5)*	*6.1(0.5)*	*6.1(0.5)*
Posa	-	25	8.2(0.7)				
Posa	10	25		*6.3(0.6)*	*5.3(0.4)*	*4.2(0.4)*	*3.2(0.6)*
Posa	25	25		*3.7(0.5)*	*3.4(0.3)*	*3.1(0.3)*	*2.8(0.5)*
Feov	-	10	8.7(0.9)				
Feov	10	10		*7.2(0.7)*	*5.4(0.6)*	*4.7(0.6)*	*5.1(0.7)*
Feov	25	10		*5.1(0.5)*	*4.8(0.3)*	*4.5(0.3)*	*4.3(0.5)*
Feov	-	25	4.1(0.7)				
Feov	10	25		*2.7(0.7)*	*2.7(0.7)*	*2.7(0.7)*	*2.7(0.7)*
Feov	25	25		*2.2(0.3)*	*2.0(0.2)*	*1.8(0.2)*	*1.6(0.3)*
Agda	-	10	7.9(0.6)				
Agda	10	10		*6.4(0.4)*	*6.0(0.3)*	*5.5(0.3)*	*5.0(0.4)*
Agda	25	10		*5.4(0.5)*	*4.5(0.4)*	*4.0(0.4)*	*4.0(0.5)*
Agda	-	25	2.8(0.2)				
Agda	10	25		*2.1(0.2)*	*2.0(0.1)*	*1.9(0.1)*	*1.8(0.2)*
Agda	25	25		*1.9(0.1)*	*1.8(0.1)*	*1.8(0.1)*	*1.7(0.1)*
Brte (K)	-	10	4.0(0.3)				
Brte (O)	-	10	3.6(0.2)				
Brte (T)	-	10	4.0(0.6)				
Brte (K)	-	25	1.8(0.1)				
Brte (O)	-	25	2.3(0.6)				
Brte (T)	-	25	1.6(0.2)				

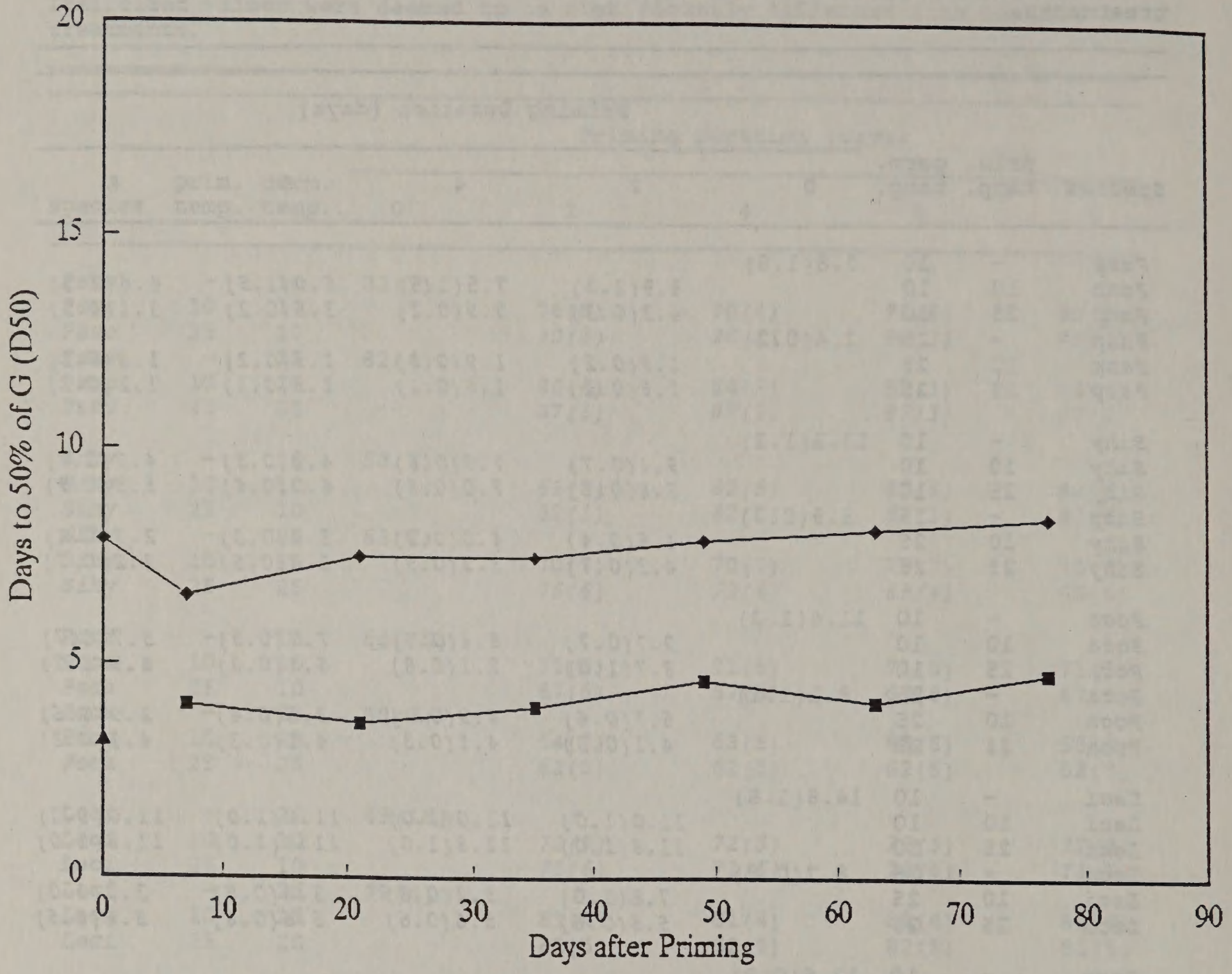

Figure 1 - Germination rate response (D_{50}) of non-primed control (◆), freshly primed (▲), and primed-redried (■) seeds of bluebunch wheatgrass.

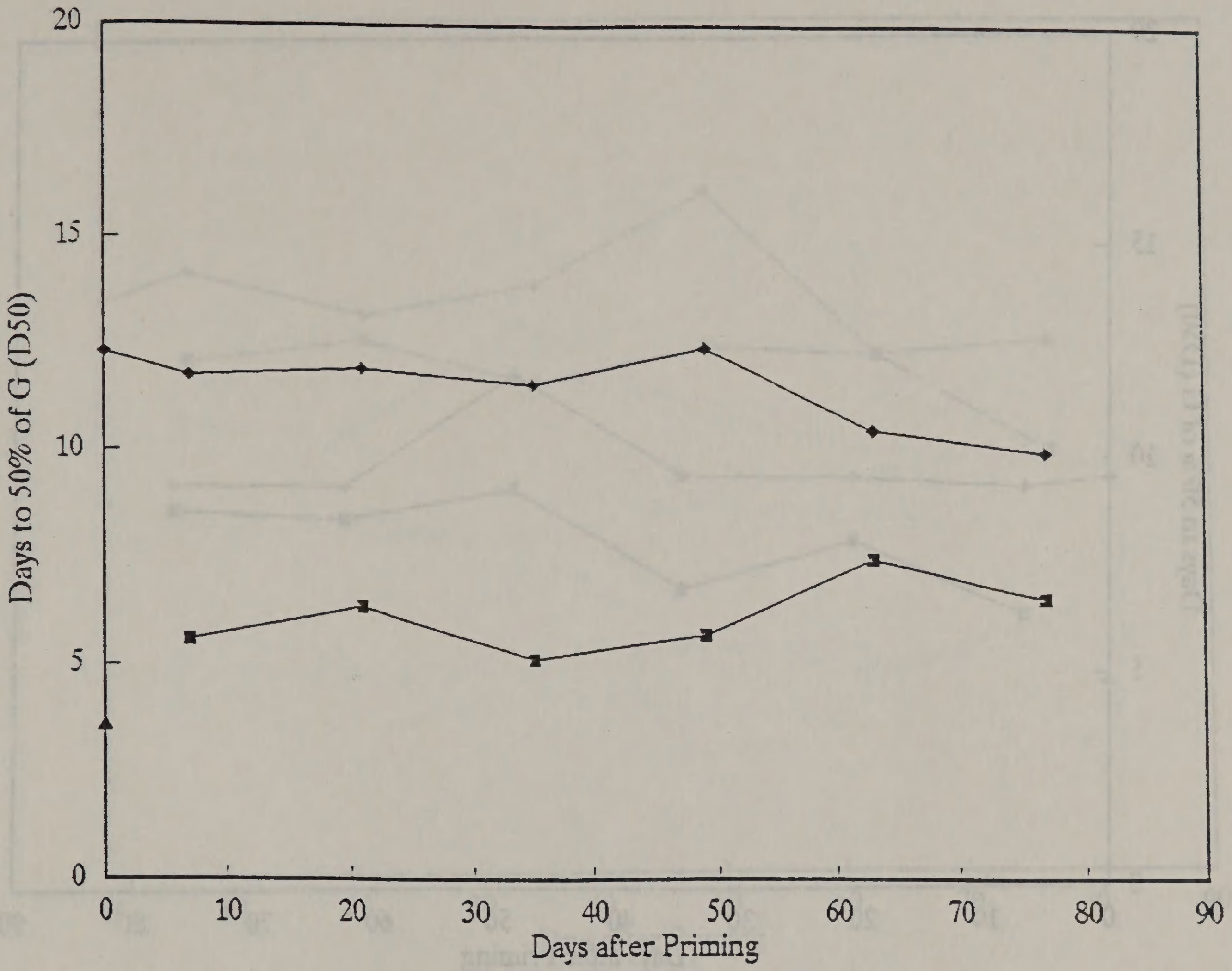

Figure 2 - Germination rate response (D_{50}) of non-primed control (◆), freshly primed (▲), and primed-redried (■) seeds of bottlebrush squirreltail.

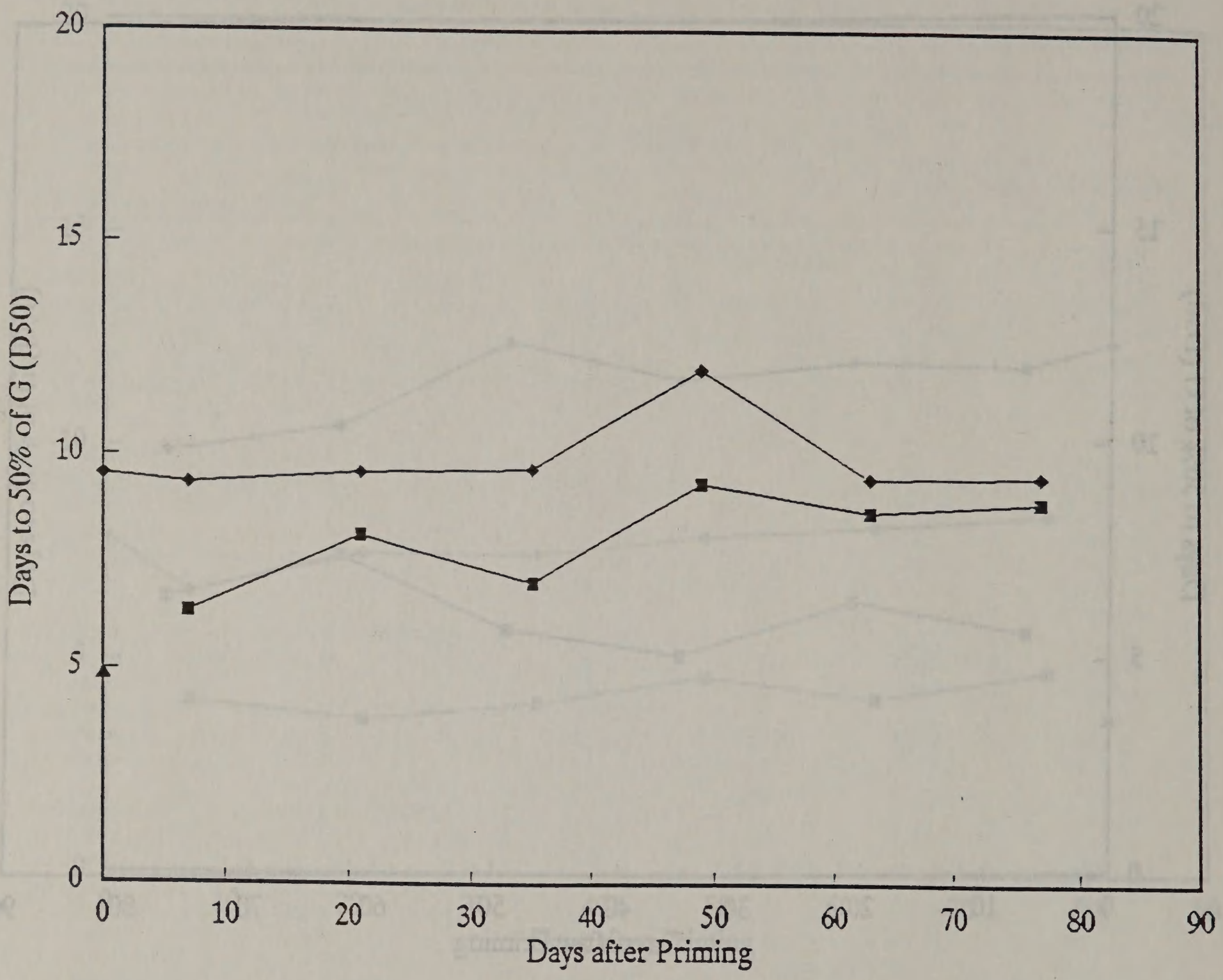

Figure 3 - Germination rate response (D_{50}) of non-primed control (◆), freshly primed (▲), and primed-redried (■) seeds of canby bluegrass.

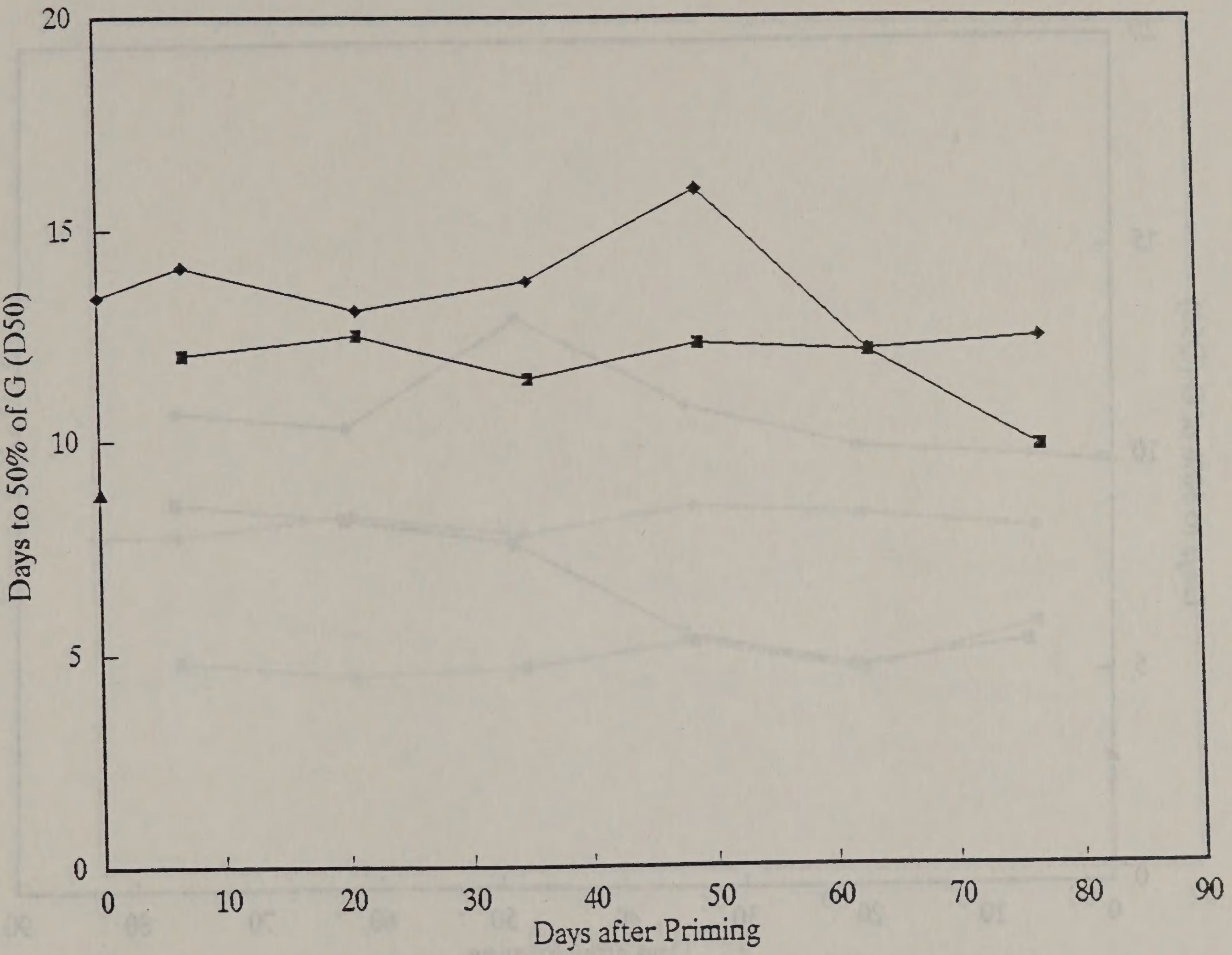

Figure 4 - Germination rate response (D_{50}) of non-primed control (◆), freshly primed (▲), and primed-redried (■) seeds of basin wildrye.

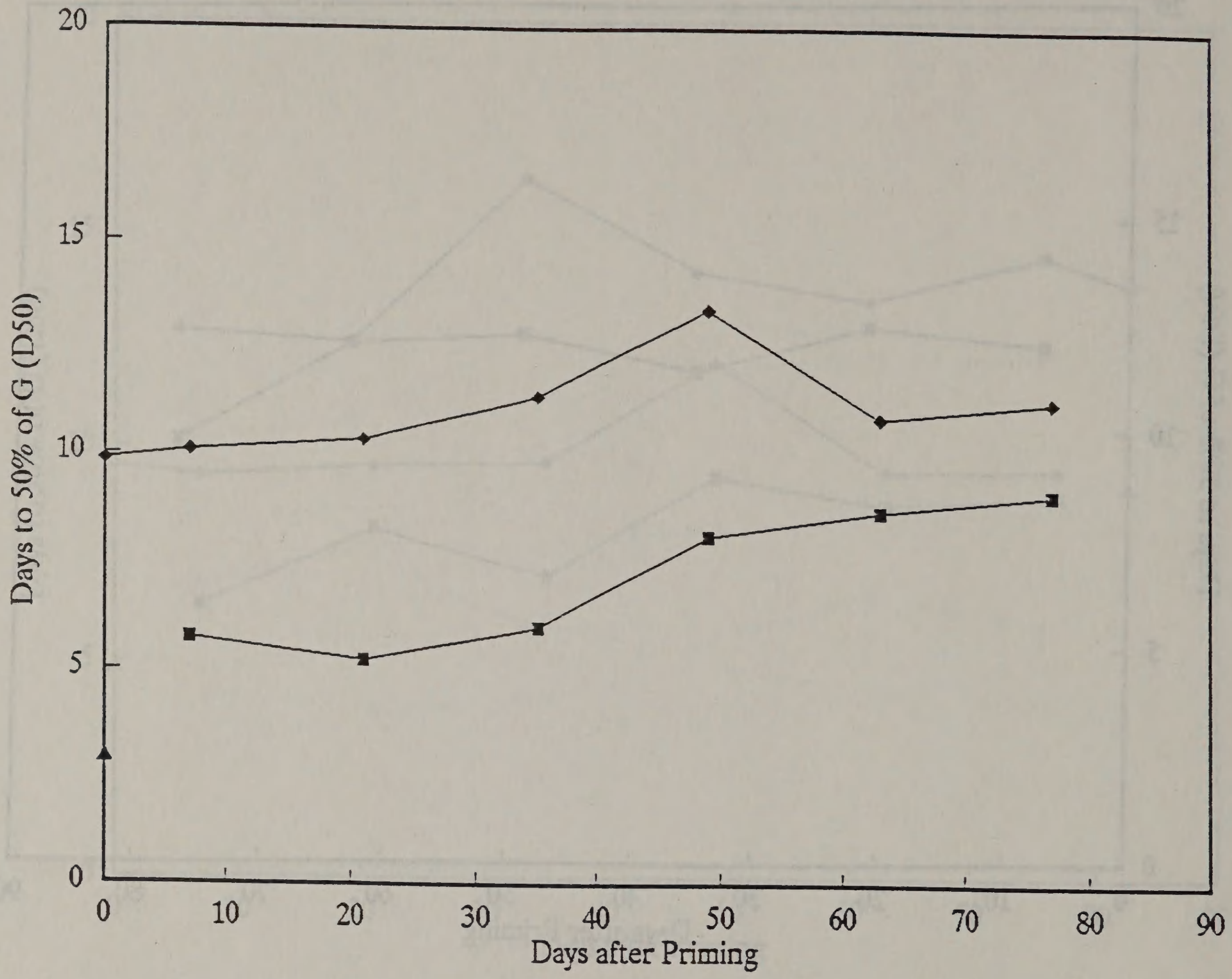

Figure 5 - Germination rate response (D_{50}) of non-primed control (◆), freshly primed (▲), and primed-redried (■) seeds of Sandberg bluegrass.

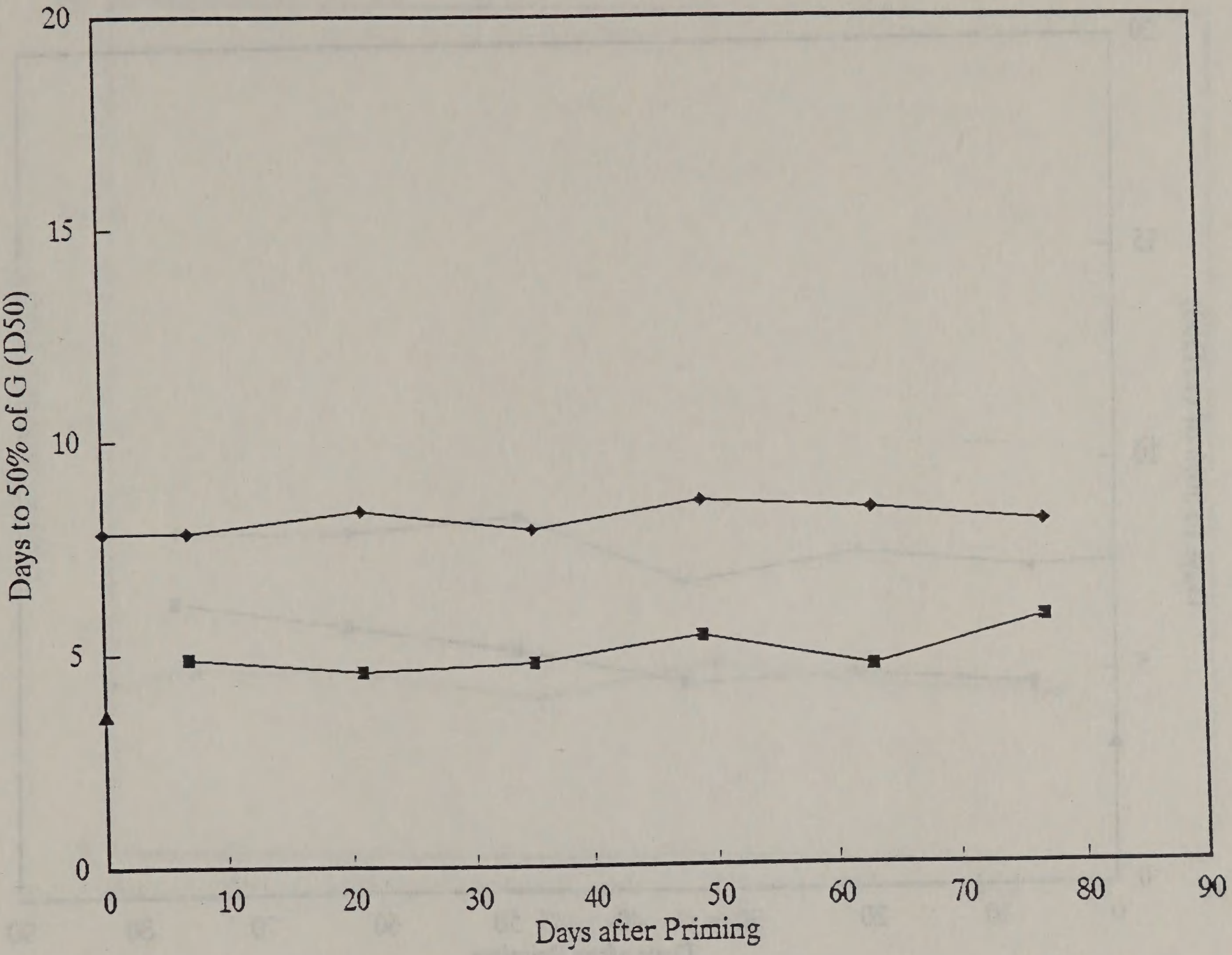

Figure 6 - Germination rate response (D_{50}) of non-primed control (◆), freshly primed (▲), and primed-redried (■) seeds of thickspike wheatgrass.

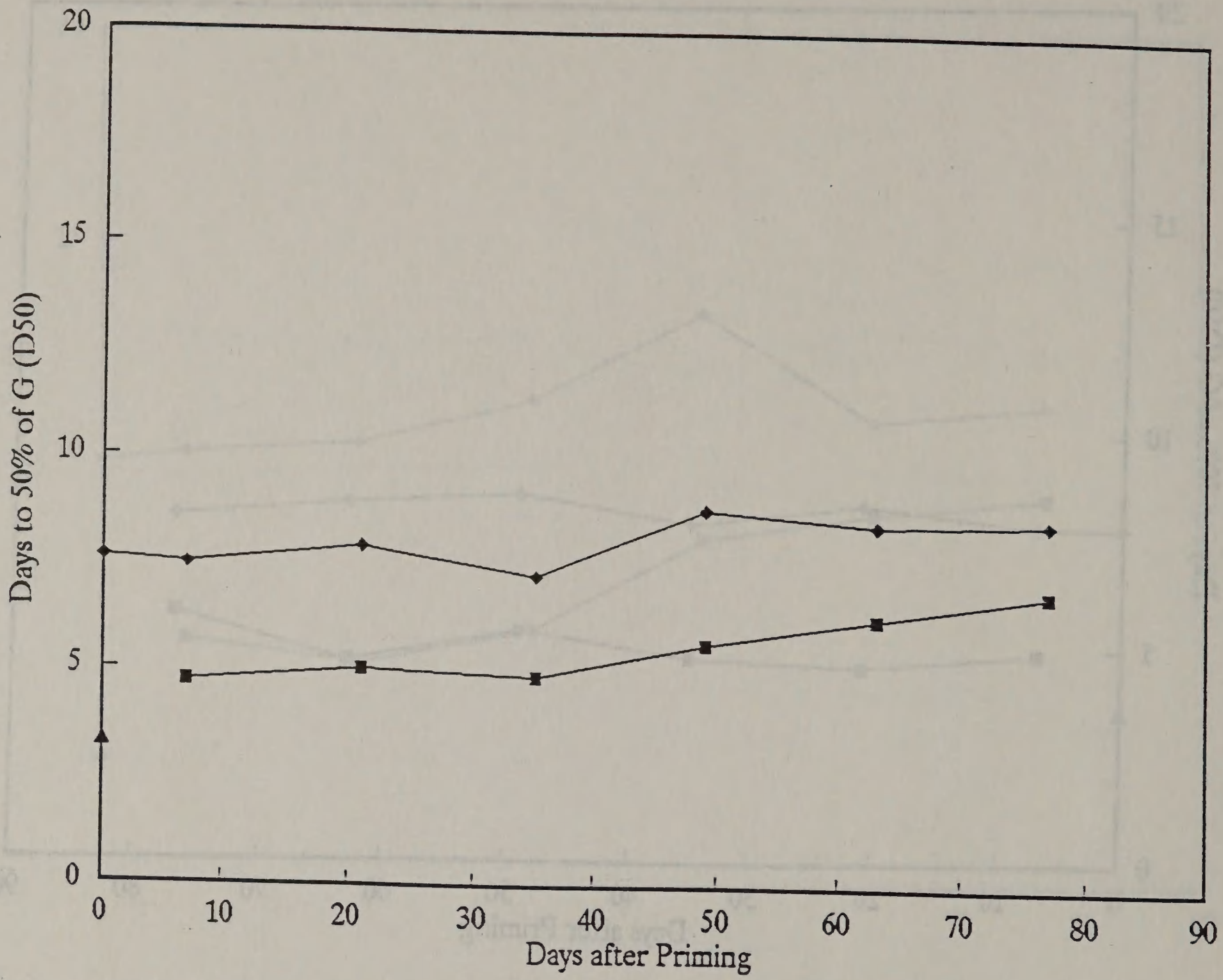

Figure 7 - Germination rate response (D_{50}) of non-primed control (◆), freshly primed (▲), and primed-redried (■) seeds of sheep fescue.

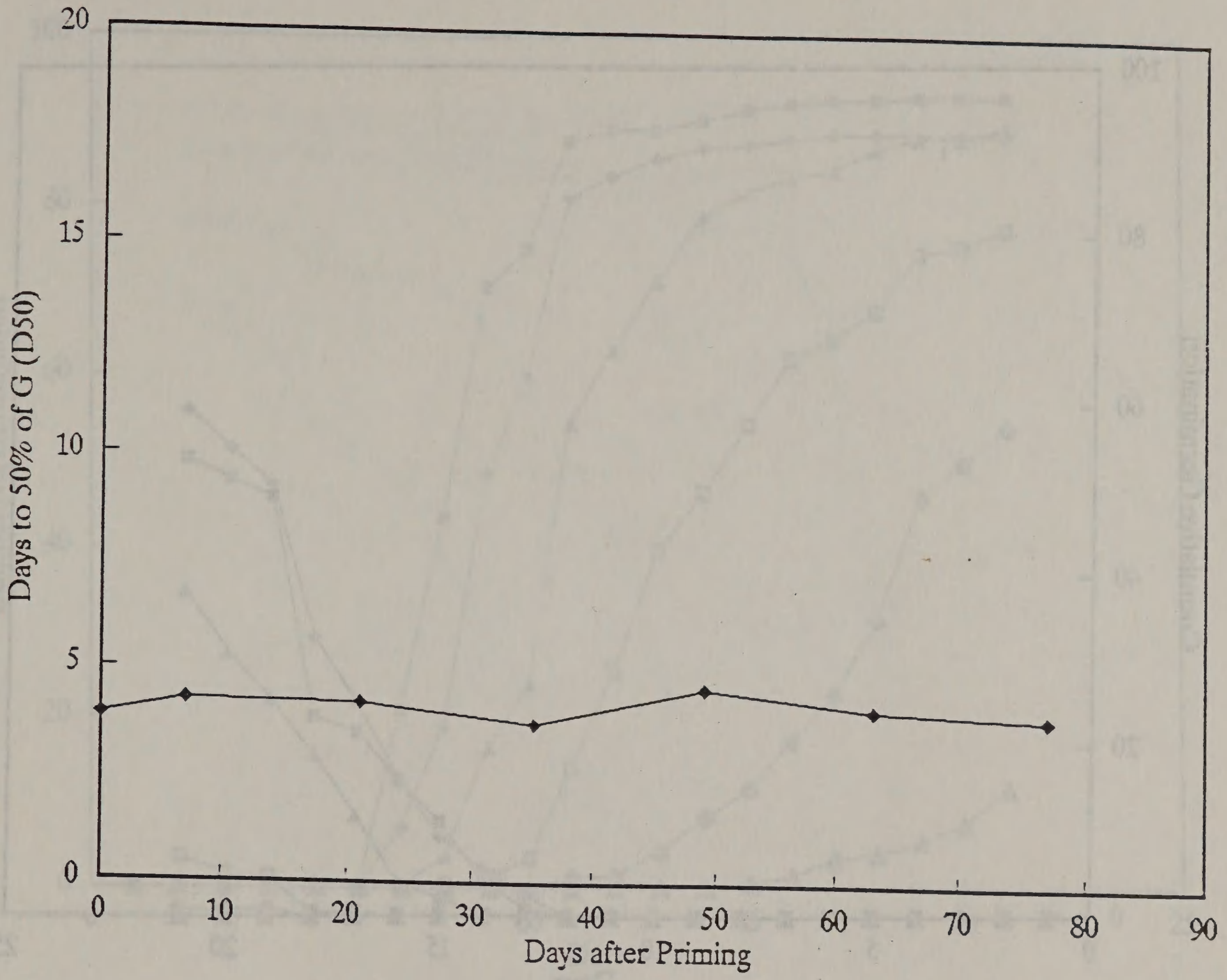

Figure 8 - Mean germination rate response (D_{50}) of three accessions of non-primed control (◆) seeds of cheatgrass.

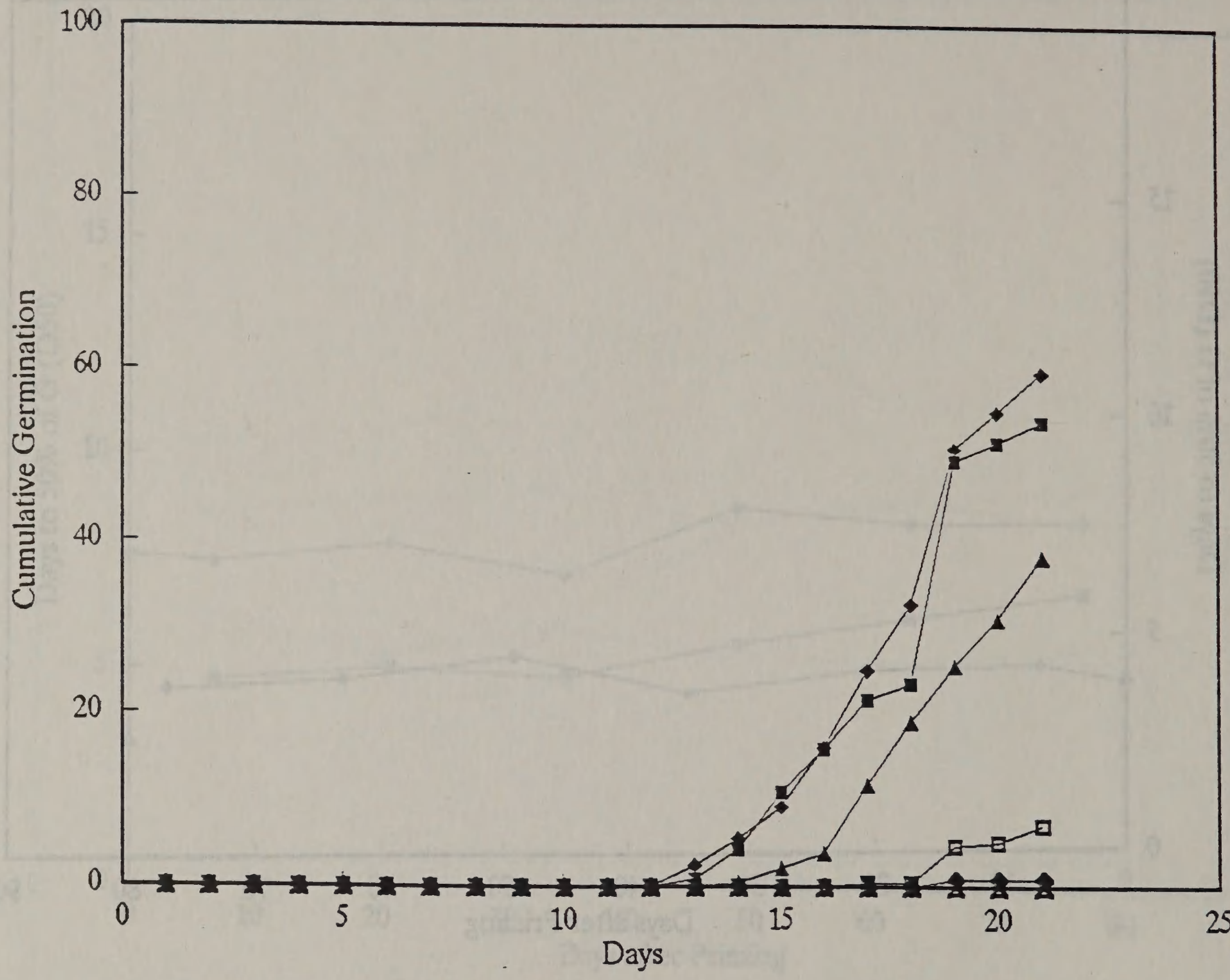

Figure 9 - Cumulative germination profile for thickspike wheatgrass at 5°C and 0 (■), -0.1 (◆), -0.4 (▲), -0.7 (□), -1.0 (◇) and -1.3 MPa water potential (△).

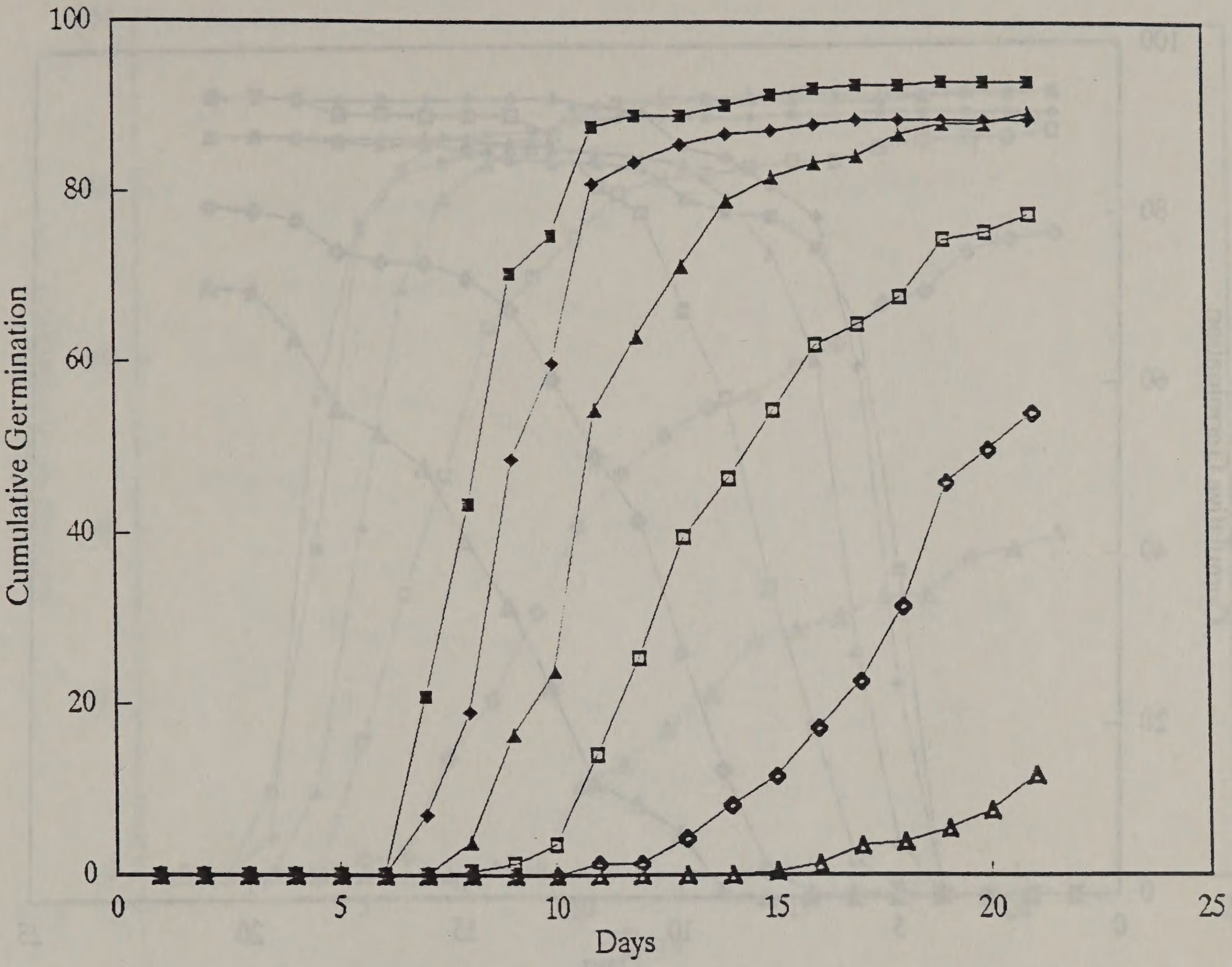

Figure 10 - Cumulative germination profile for thickspike wheatgrass at 10 °C and 0 (■), -0.1 (◆), -0.4 (▲), -0.7 (□), -1.0 (◇) and -1.3 MPa water potential (△).

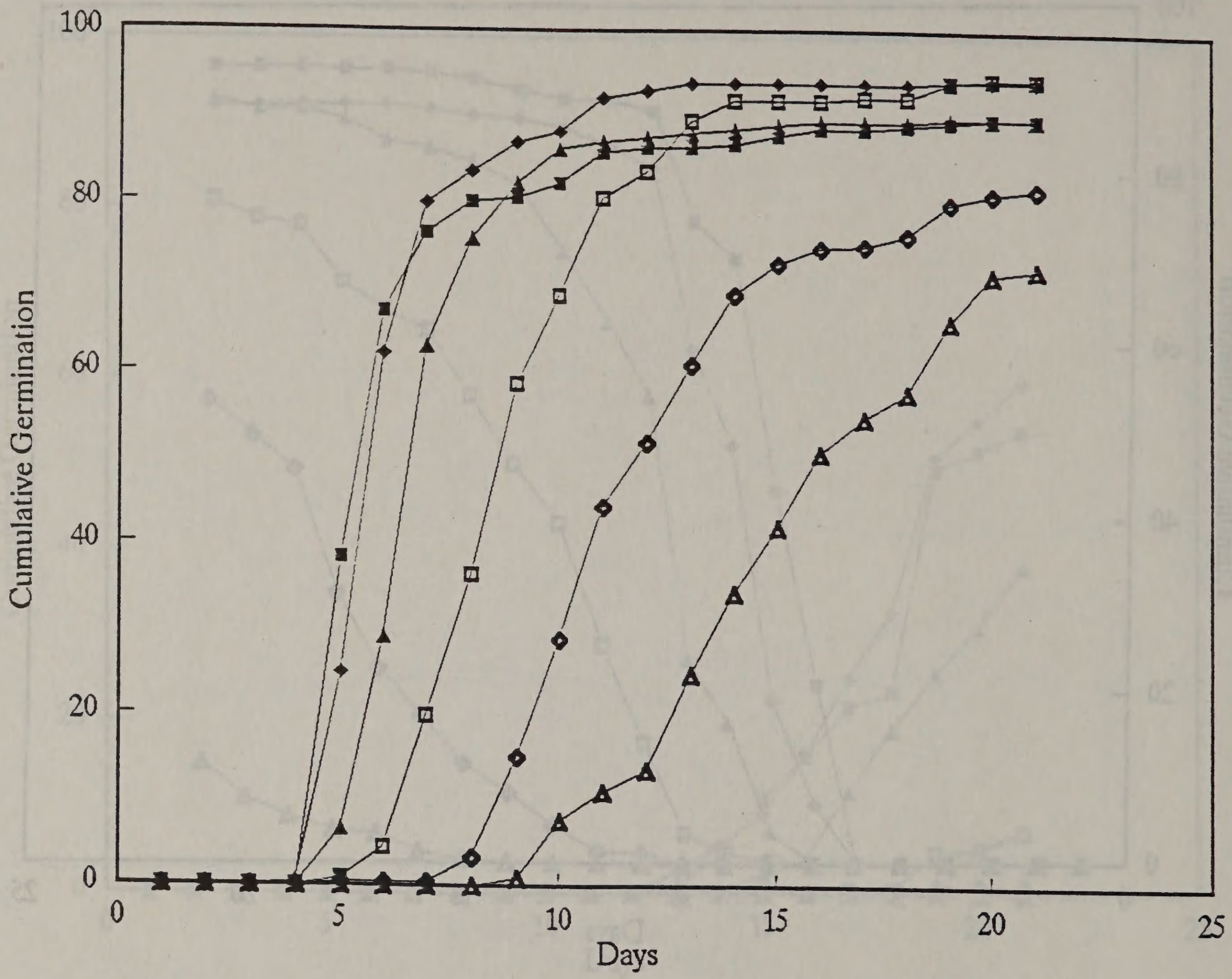

Figure 11 - Cumulative germination profile for thickspike wheatgrass at 15°C and 0 (■), -0.1 (◆), -0.4 (▲), -0.7 (□), -1.0 (◇) and -1.3 MPa water potential (△).

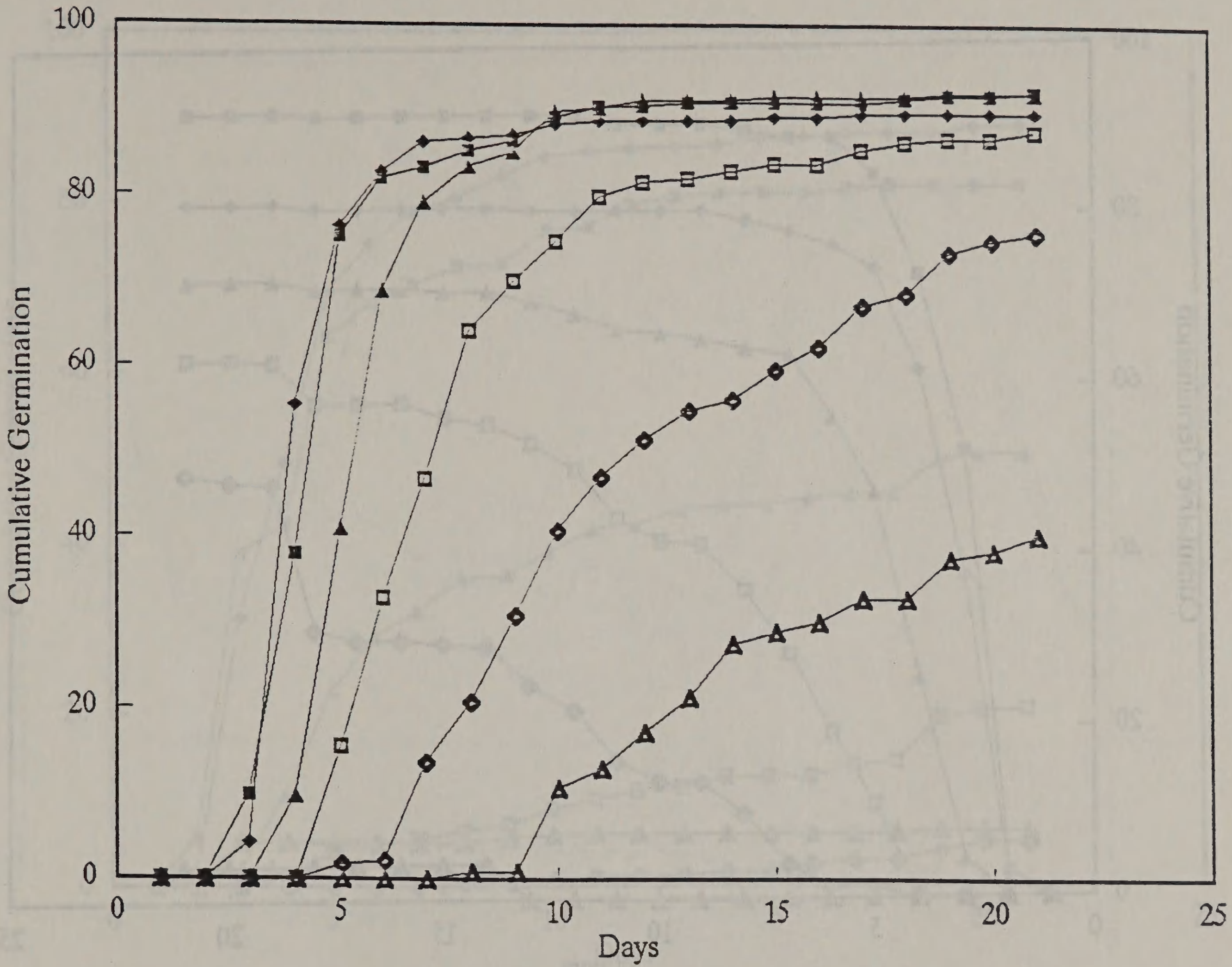

Figure 12 - Cumulative germination profile for thickspike wheatgrass at 20 °C and 0 (■), -0.1 (◆), -0.4 (▲), -0.7 (□), -1.0 (◇) and -1.3 MPa water potential (△).

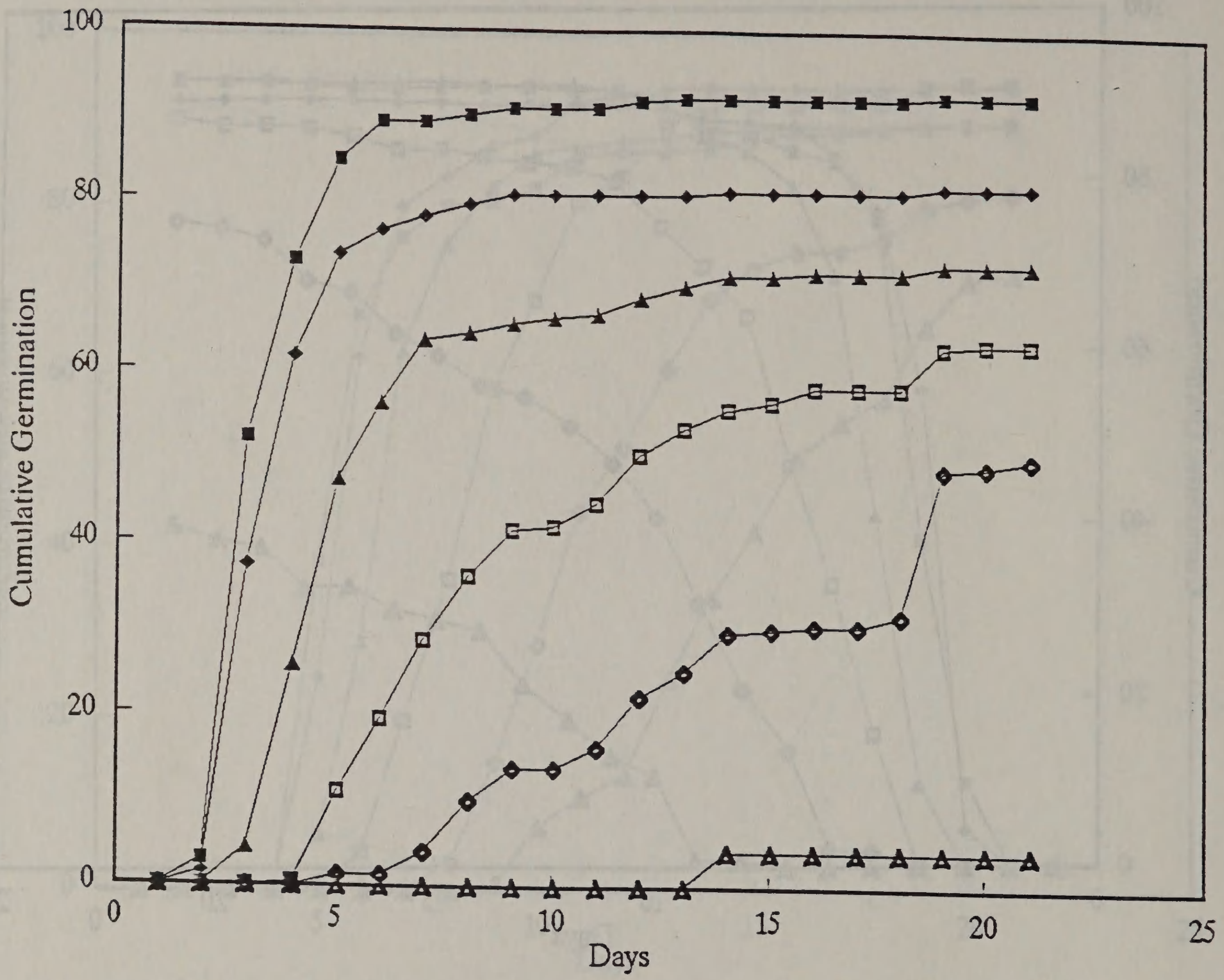

Figure 13 - Cumulative germination profile for thickspike wheatgrass at 25 °C and 0 (■), -0.1 (◆), -0.4 (▲), -0.7 (□), -1.0 (◇) and -1.3 MPa water potential (△).

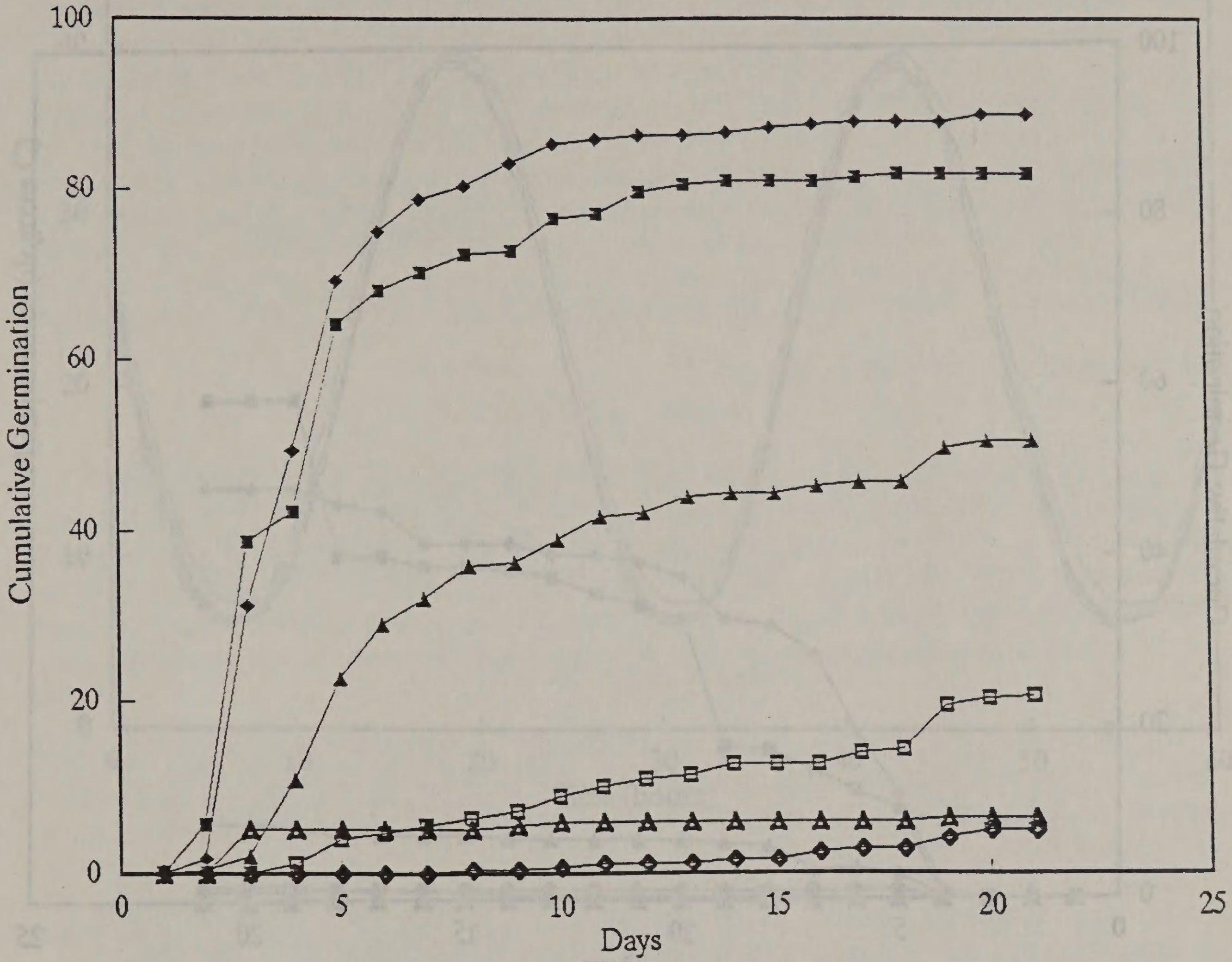

Figure 14 - Cumulative germination profile for thickspike wheatgrass at 30 °C and 0 (■), -0.1 (◆), -0.4 (▲), -0.7 (□), -1.0 (◇) and -1.3 MPa water potential (△).

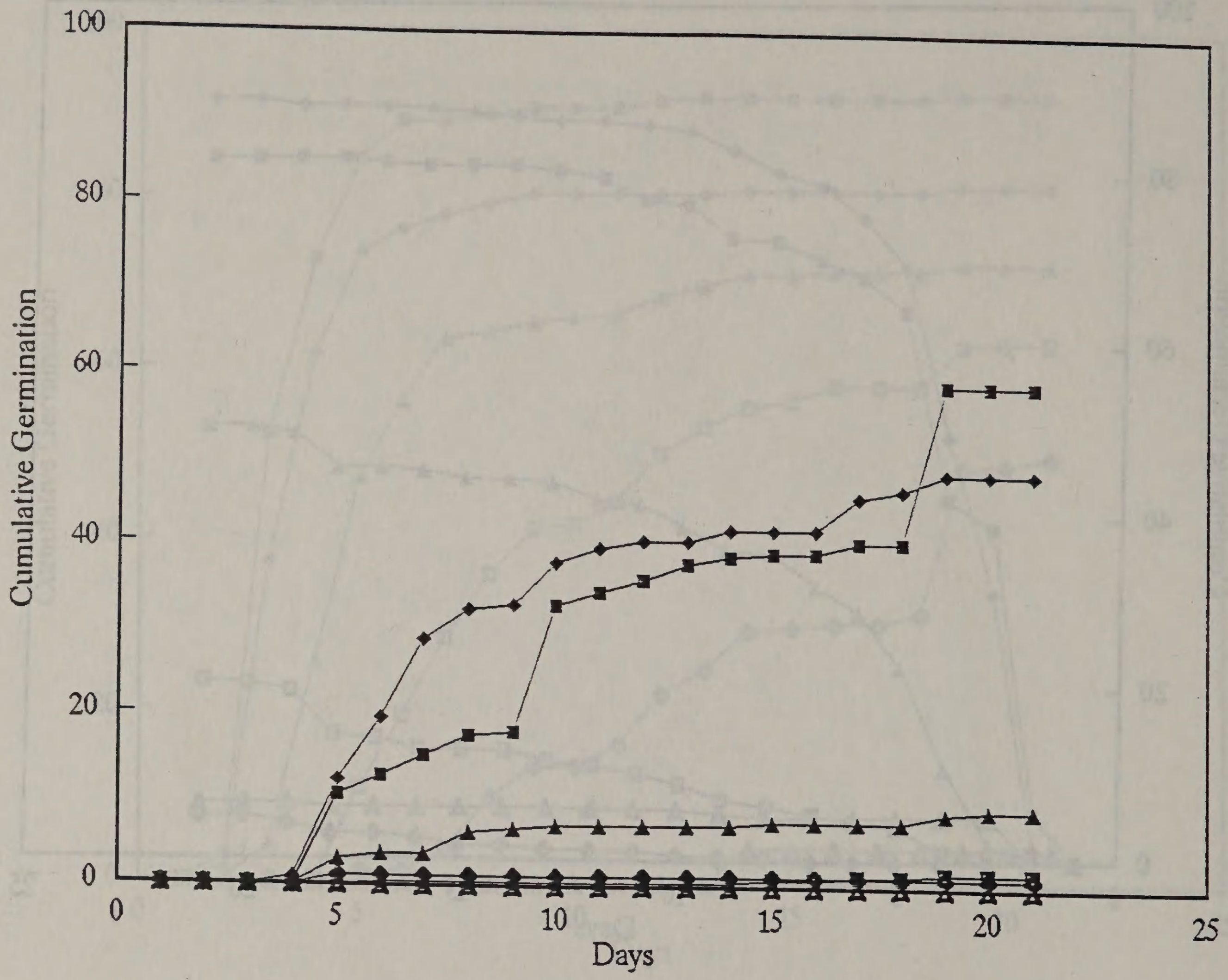

Figure 15 - Cumulative germination profile for thickspike wheatgrass at 35 °C and 0 (■), -0.1 (◆), -0.4 (▲), -0.7 (□), -1.0 (◇) and -1.3 MPa water potential (△).

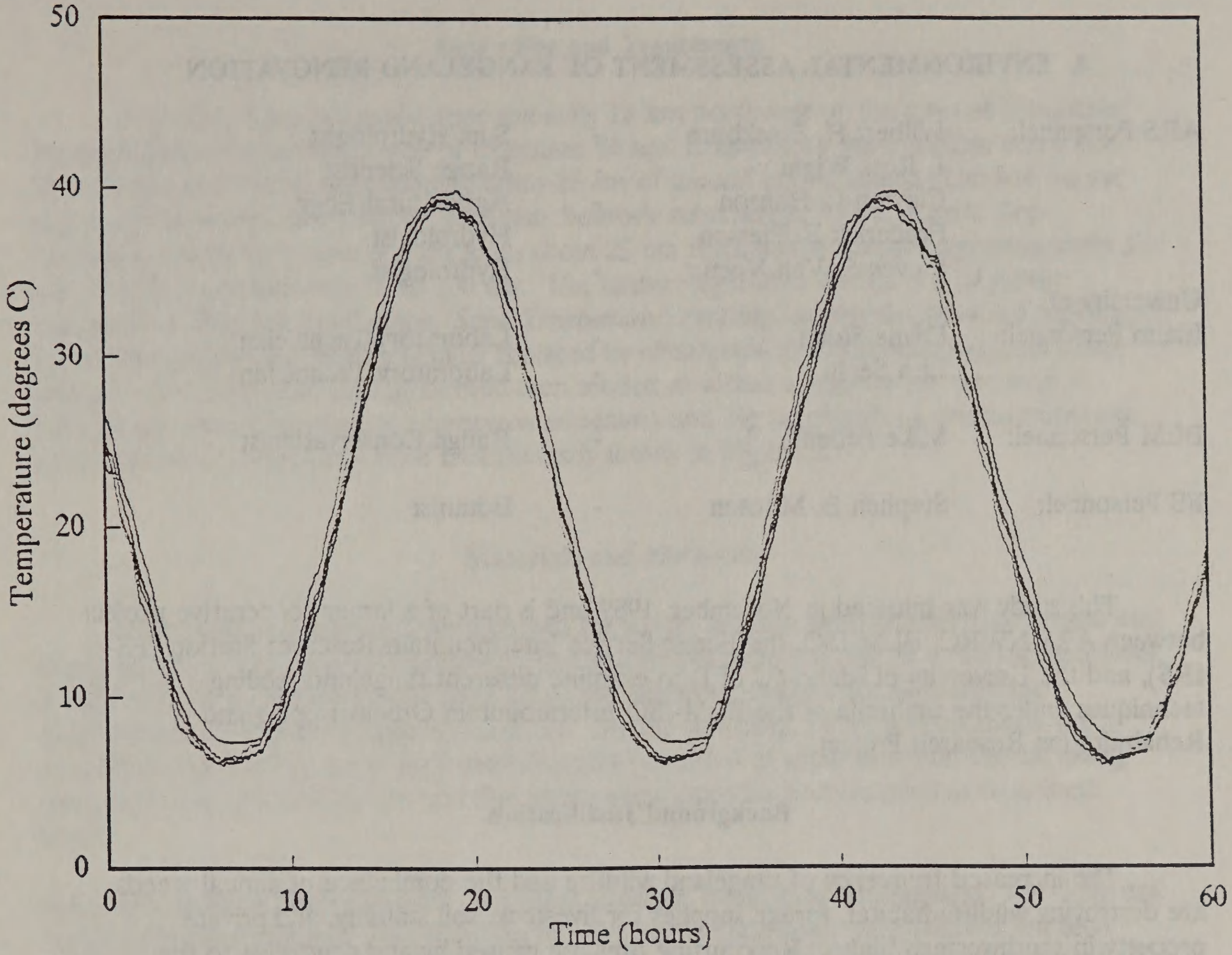

Figure 16 - Mean germination vial temperature on each of four levels in our prototype germinator during simulation of a sine-wave variable-temperature regime.

4. ENVIRONMENTAL ASSESSMENT OF RANGELAND RENOVATION

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BLM Personnel:	Mike Pellent	-	Range Conservationist
FS Personnel:	Stephen B. Monsen	-	Botanist

This study was initiated in November, 1989 and is part of a larger cooperative project between ARS-NWRC, BLM-ISO, the Forest Service Intermountain Research Station (FS-IRS), and the University of Idaho (U of I) to examine different rangeland seeding techniques under the umbrella of the BLM-ISO Intermountain Greenstripping and Rehabilitation Research Project.

Background/Justification

The increased frequency of rangeland wildfire and the dominance of annual weeds are destroying wildlife habitat, forage supplies for livestock, soil stability, and private property in southwestern Idaho. Reoccurring fires are caused by and conducive to the presence of annual weeds, specifically cheatgrass (*Bromus tectorum*). Establishment of perennial native plant species is critical to maintaining the productivity and stability of this multipurpose rangeland resource. Current restoration and management of these rangelands is often ineffective due to a lack of understanding of the fundamental physical processes involved. To improve restoration efforts, technology is needed which can predict the seedbed environment, as well as the soil erosion hazard of different restoration techniques. This can be achieved by improving our understanding of the environmental processes influencing seedling establishment and site stability.

Objectives

A. To assess the influence of land surface modifications associated with seeding on:
   1. The seed micro-climate
   2. Spatial and temporal variability of surface soil properties
   3. Runoff and erosion

B. To develop and test physically-based algorithms and models to simulate surface soil water/temperature regimes, with sufficient accuracy to be useful in the prediction of seed germination and establishment, and thus enhance the success of seeding treatments.

C. To test, refine and develop the WEPP model as a tool to predict surface runoff and erosion from range sites modified by rangeland renovation techniques.

Study Site and Treatments

The study area is located approximately 13 km northwest of the town of Mountain Home adjacent to the south side of interstate 84 and is known as the Lockman study site. The elevation is 970 m with approximately 28 cm of annual precipitation. The soil on the site is characterized as a Chilcott silt loam, bedrock substratum, 0 to 2 percent slope. Typically, the surface layer is a silt loam about 23 cm thick and a hardpan approximately 50 cm thick is found between 50 to 100 cm. The native vegetation on the site originally consisted of Thurber needlegrass (*Stipa Thurberiana*) and big sagebrush (*Artemisia tridentata wyomingensis*) but has been gradually replaced by cheatgrass (*Bromus tectorum*) and other annuals. The area was initially burned then seeded at either a high or low rate with a mixture of crested wheatgrass (*Agropyron cristatum*) and big sagebrush (*Artemisia tridentata wyomingensis*). A field layout of treatments is shown in Figure 2.1.

Materials and Methods

Two reseeding methods were chosen for study: burned amazon drill and burned disk chain with a burned control treatment. The treatments were laid out in a randomized block design with three replications (Figure 2.1). The sampling designs for all treatment replications are shown in Figures (2.2-2.10). During sampling, 10 sample locations are randomly stratified within in each sampling plot (outlined in small boxes on the sampling designs) to include five furrow and five interspaces locations and sampled as described below.

***Soil and Vegetation Measurements*:** Soil shear strength, penetrometer resistance and 2-cm soil temperature are sampled once a month for 10 months each year. Soil samples are also collected and analyzed for moisture content, bulk density and wet aggregate stability. Soil samples were analyzed once for organic carbon content and soil texture during FY-1990, but were analyzed each sample period after October, 1990. In addition, permanent transects have been established in each treatment replication to monitor surface micro-relief and surface cover. The transects were read at the initiation of the study and will continue to be read once a year in the spring.

***Rainfall Simulation Measurements*:** Each year beginning in June/July, 1990 a rotating-boom rainfall simulator is used to simulate rainfall on two plots (3.05 m X 10.67 m) within each treatment and replication. Rainfall simulation on each plot is done once for 1 hr under existing antecedent moisture conditions and once for 0.5 hr 24 hrs later at or near field capacity soil moisture. Plot runoff is continuously recorded with an ISCO Bubbler Gauge. Sediment samples are collected every 2 min after runoff begins until runoff increases to a constant rate and then samples are taken every 4 min. In addition, soil and vegetation data as described above are also collected at the time of rainfall simulation.

***Soil Micro-climate*:** Soil water and temperature sensors were placed in six furrow and six interfurrow locations in one disk-chain, one amazon drill and one control treatment at depths and spacings indicated in Figure 2.11. The sensors are monitored every ten minutes and average hourly values are stored on data logging systems. A weather station was also established at the site to monitor precipitation, solar radiation, air temperature, relative humidity and wind on an hourly basis.

*** See Appendix I for more information on experimental procedures and additional tables and figures which show more detail of the data presented in this section.

Preliminary Results

The following tables and figures represent a summary of all project field data collected to date. The data is organized into three general categories: 1) soil and vegetation data, 2) rainfall simulation data, and 3) soil micro-climate data.

Table 2.1. Organic Carbon Content (%) by Replication (Rep) and Date of the Permenant Transects. Lockman Study Site, Mountain Home, Idaho. Composite soil sample of 10/rep.

Sample Date	Treatment	Organic Carbon (%) Rep 1	Rep 2	Rep 3	Average of Reps
11/20/89*	Control	1.55	1.79	1.63	1.65
	Amazon	1.53	2.08	1.50	1.70
	Disk Chain	0.91	0.65	1.24	0.94
10/04/90	Control	1.57	1.04	1.19	1.27
	Amazon	1.47	1.56	1.14	1.39
	Disk Chain	0.97	1.14	0.82	0.98
11/05/90	Control	1.78	0.82	0.72	1.11
	Amazon	1.30	2.48	1.18	1.66
	Disk Chain	1.25	0.94	1.27	1.16
12/03/90	Control	1.45	1.57	1.01	1.35
	Amazon	1.40	2.60	0.94	1.65
	Disk Chain	1.16	0.64	0.81	0.87
01/05/91	Control	1.18	1.76	1.74	1.56
	Amazon	1.43	1.54	1.08	1.35
	Disk Chain	0.56	0.80	1.51	0.95
02/01/91	Control	1.87	1.23	1.37	1.49
	Amazon	1.88	2.15	1.74	1.92
	Disk Chain	0.99	0.79	1.26	1.01
03/05/91	Control	1.48	1.42	1.04	1.31
	Amazon	0.68	0.74	0.50	0.64
	Disk Chain	1.09	0.83	1.05	0.99
03/29/91	Control	1.02	0.85	1.66	1.18
	Amazon	0.93	1.38	1.35	1.22
	Disk Chain	0.74	1.22	1.32	1.10
05/01/91	Control	1.63	1.24	0.85	1.24
	Amazon	1.73	1.88	1.15	1.59
	Disk Chain	1.02	0.93	0.97	0.97
06/03/91	Control	1.16	0.86	1.31	1.11
	Amazon	2.08	4.18	0.95	2.40
	Disk Chain	1.29	0.80	1.18	1.09
08/01/91	Control	0.70	1.23	0.76	0.89
	Amazon	1.39	1.22	1.07	1.23
	Disk Chain	1.07	0.88	1.15	1.03

* Initial sampling, taken from Interspaces and Furrows, n=10/rep.

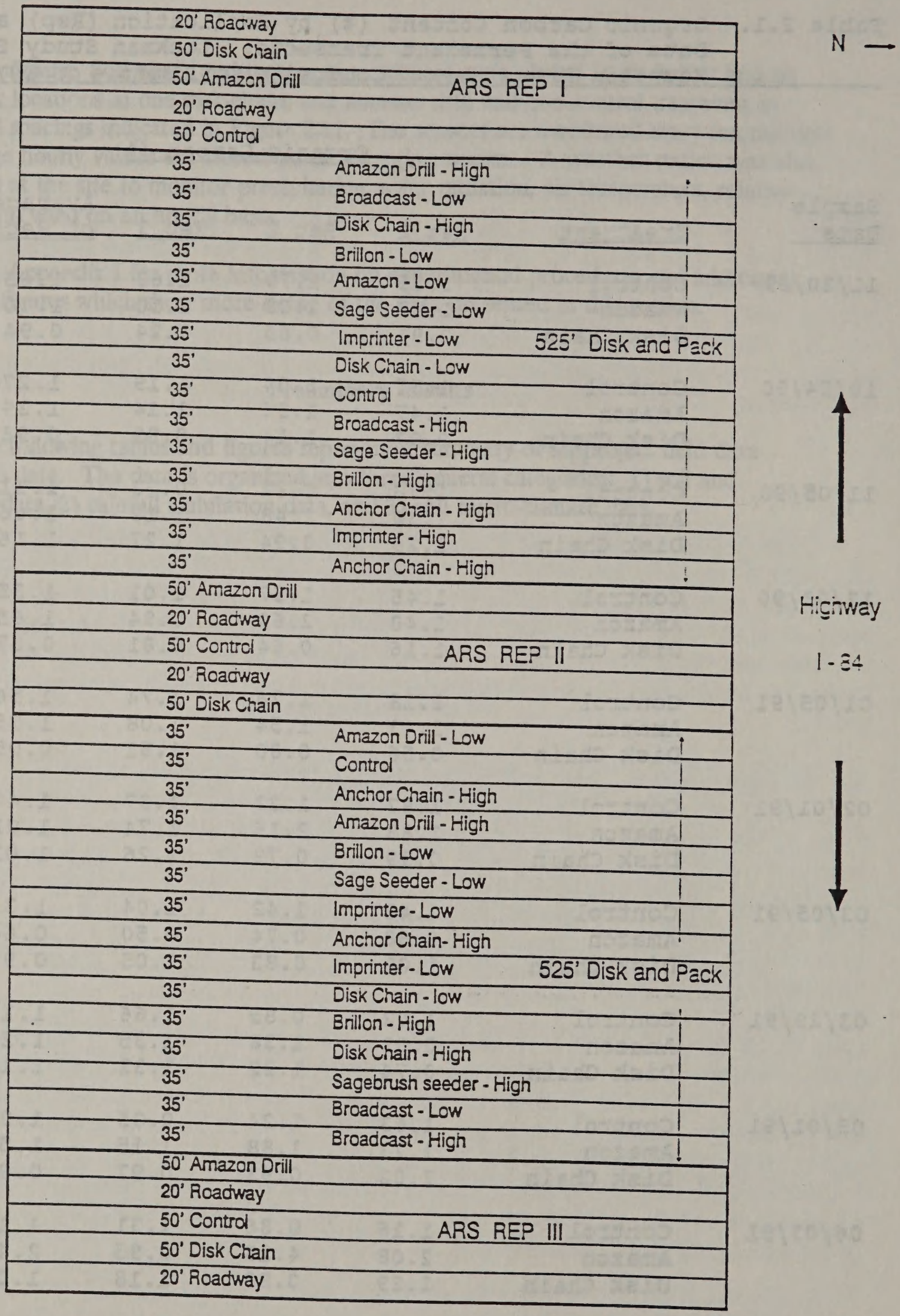


Figure 2.1 Field Layout of Seeding Treatments used at the Lockman Study Site, Mountain Home, Idaho

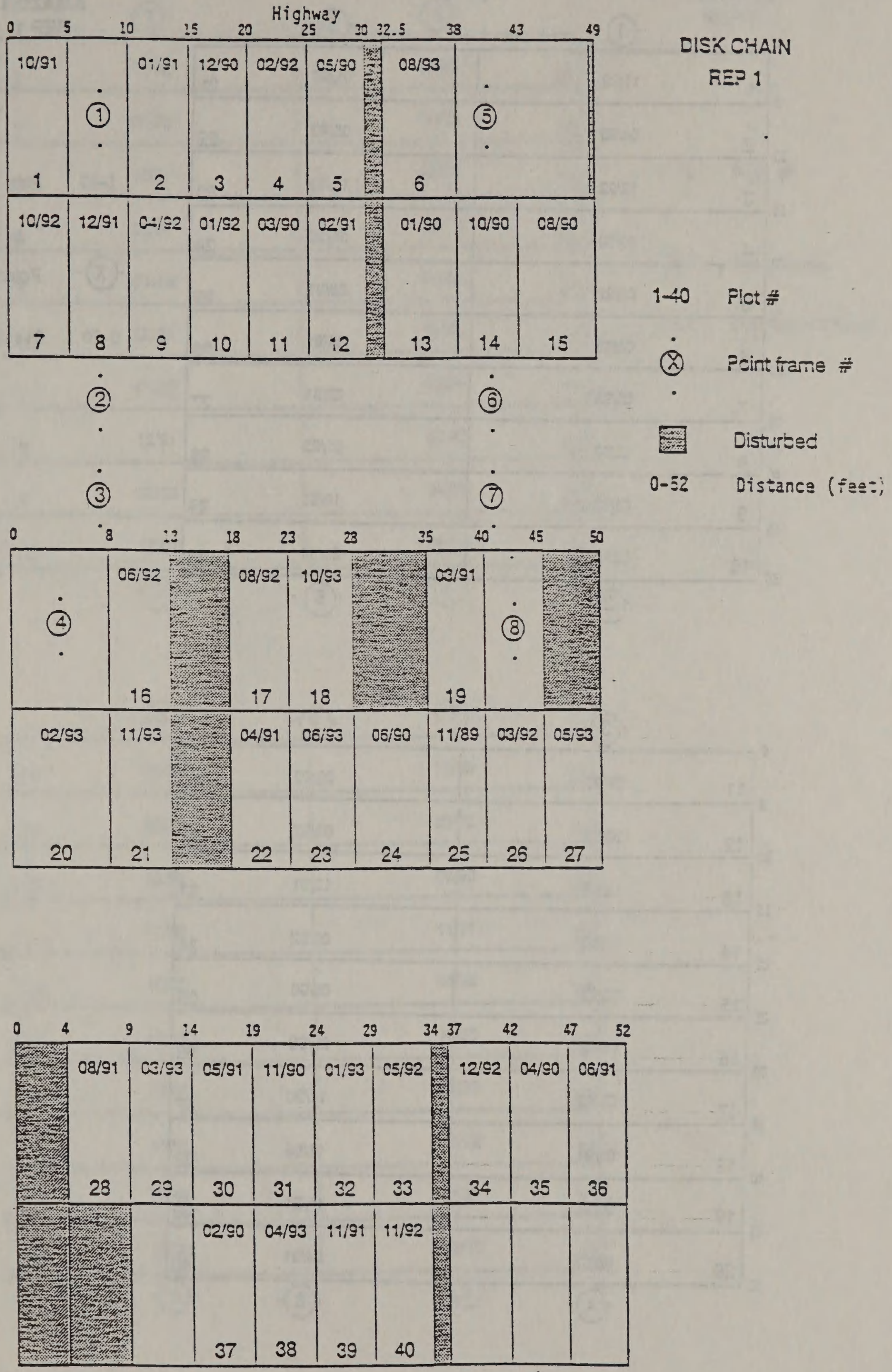


Figure 2.2 Field Layout of Sample Plots for the Disk Chain Treatment, Rep 1, at the Lockman Study Site, Mountain Home, Idaho.

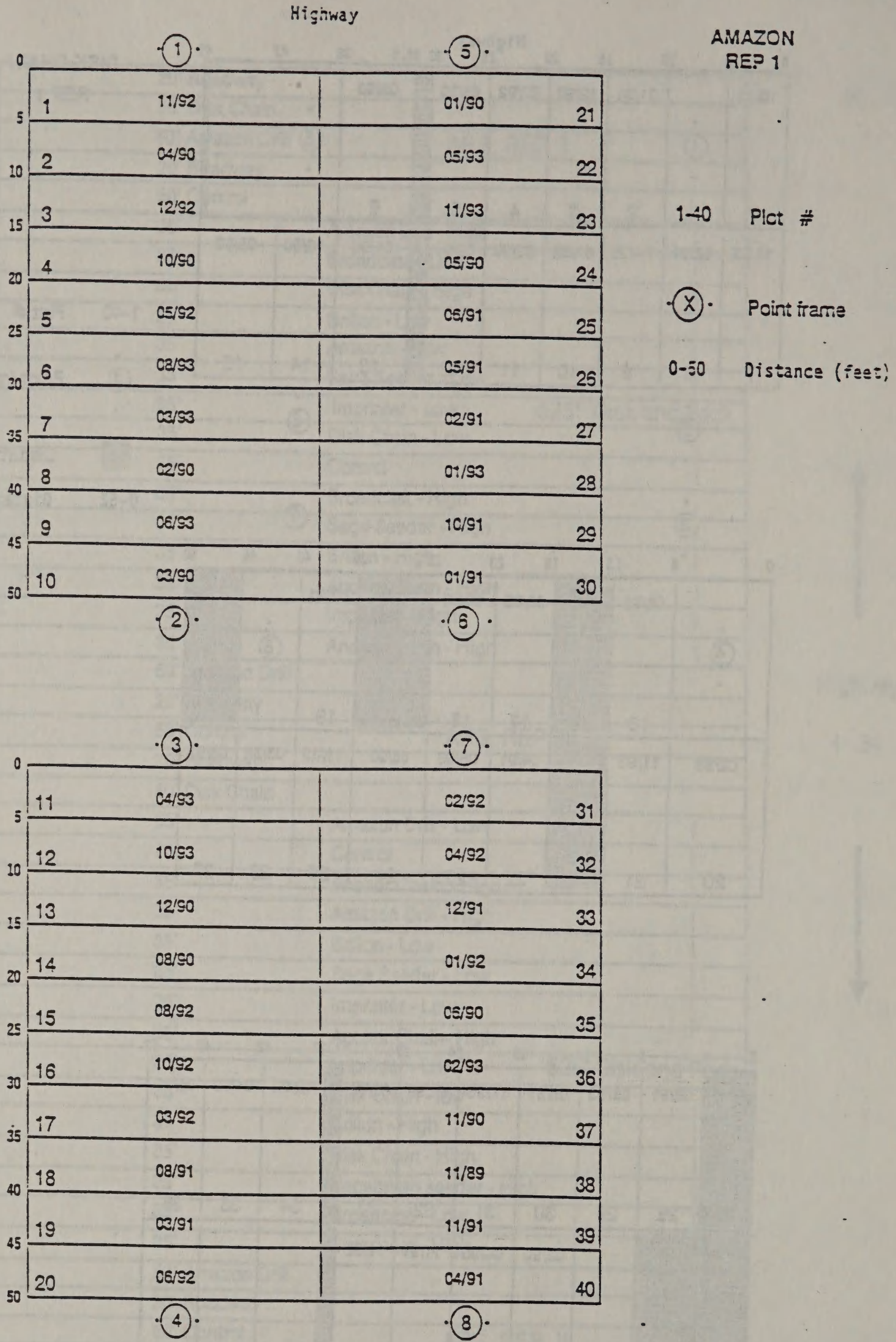


Figure 2.3 Field Layout of Sample Plots for the Amazon Drill Treatment, Rep 1, at the Lockman Study Site, Mountain Home, Idaho.

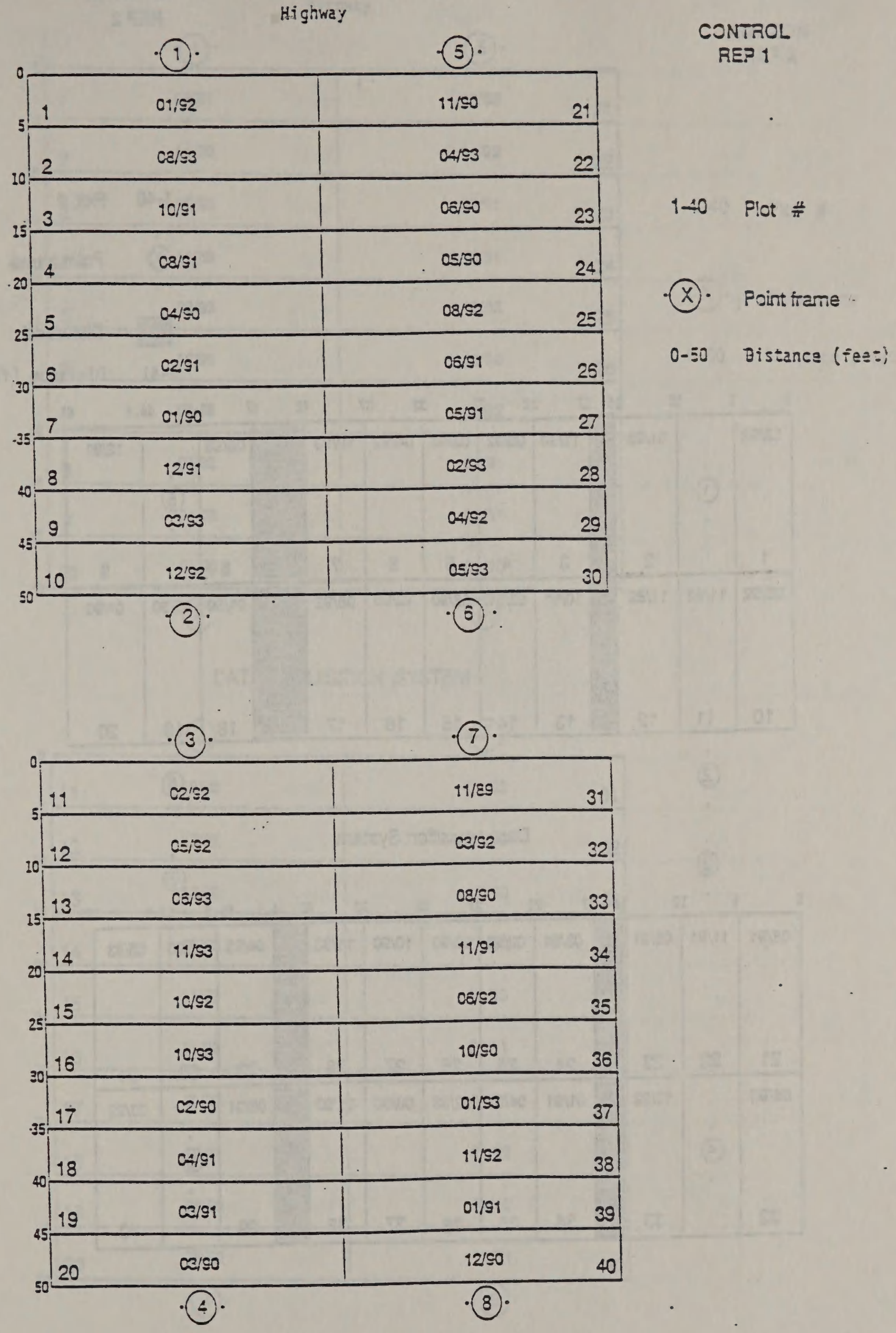


Figure 2.4 Field Layout of Sample Plots for the Control, Rep 1, at the Lockman Study Site, Mountain Home, Idaho.

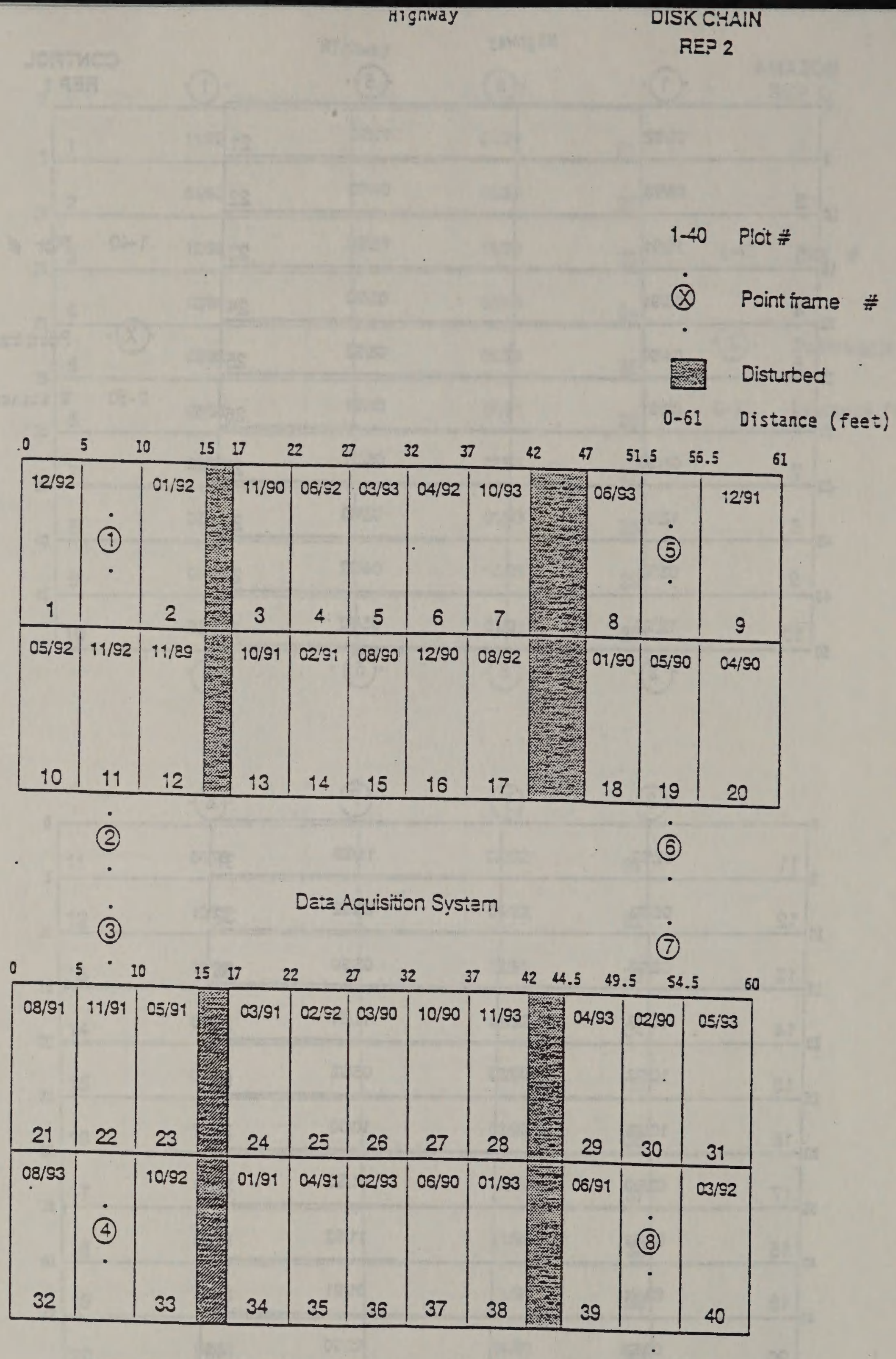


Figure 2.5 Field Layout of Sample Plots for the Disk Chain Treatment, Rep 2, at the Lockman Study Site, Mountain Home, Idaho.

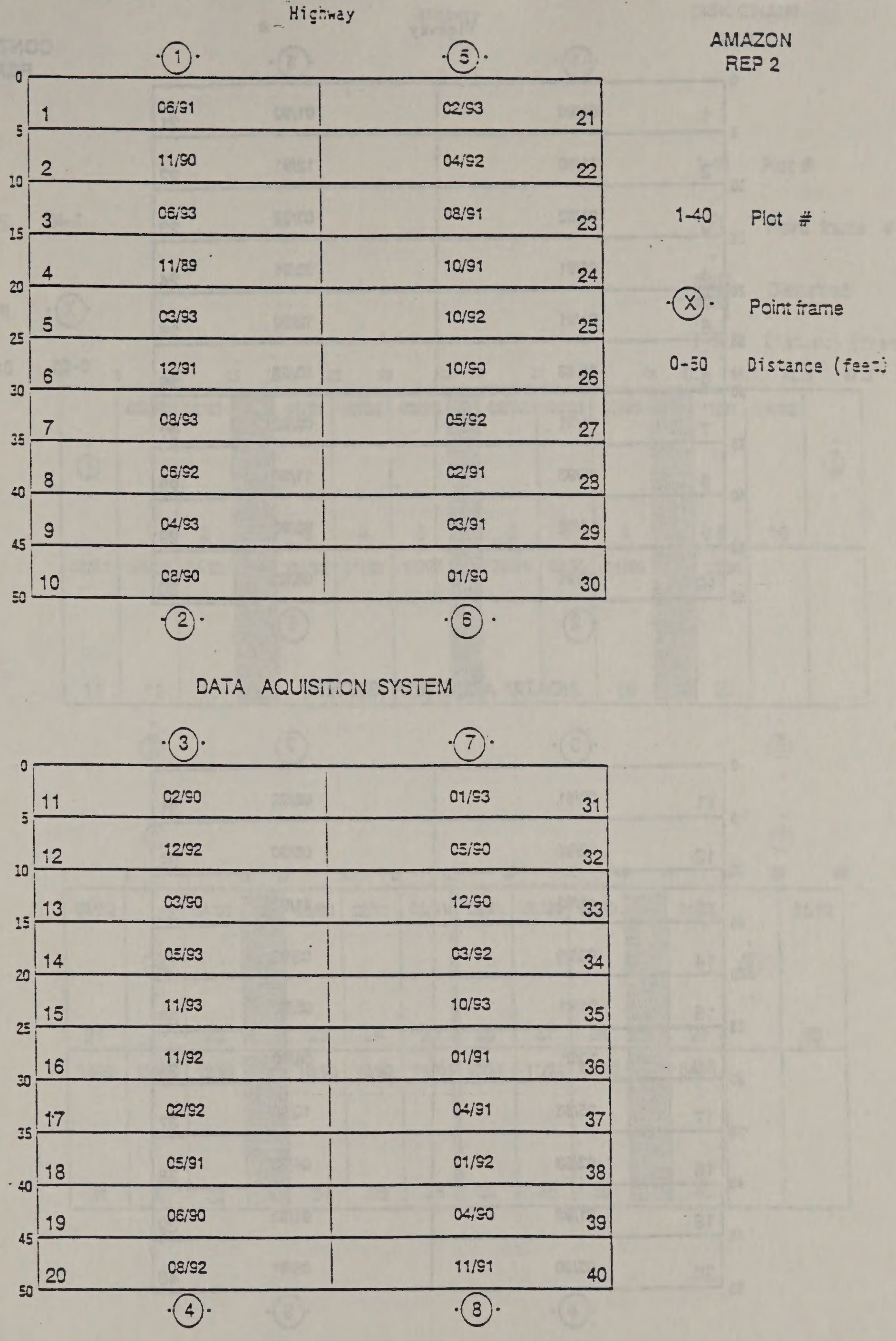


Figure 2.6 Field Layout of Sample Plots for the Amazon Drill Treatment, Rep 2, at the Lockman Study Site, Mountain Home, Idaho.

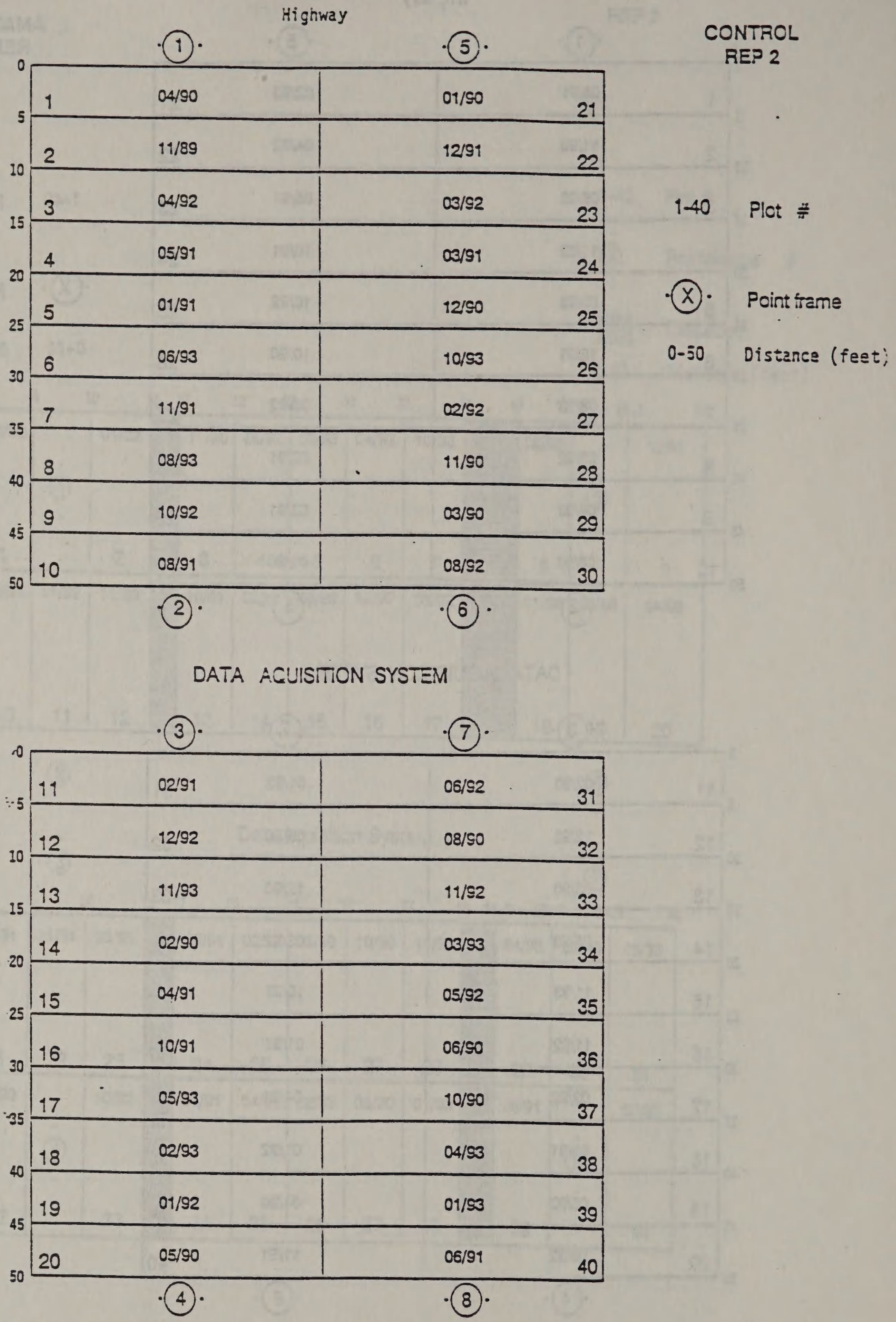


Figure 2.7 Field Layout of Sample Plots for the Control, Rep 2, at the Lockman Study Site, Mountain Home, Idaho.

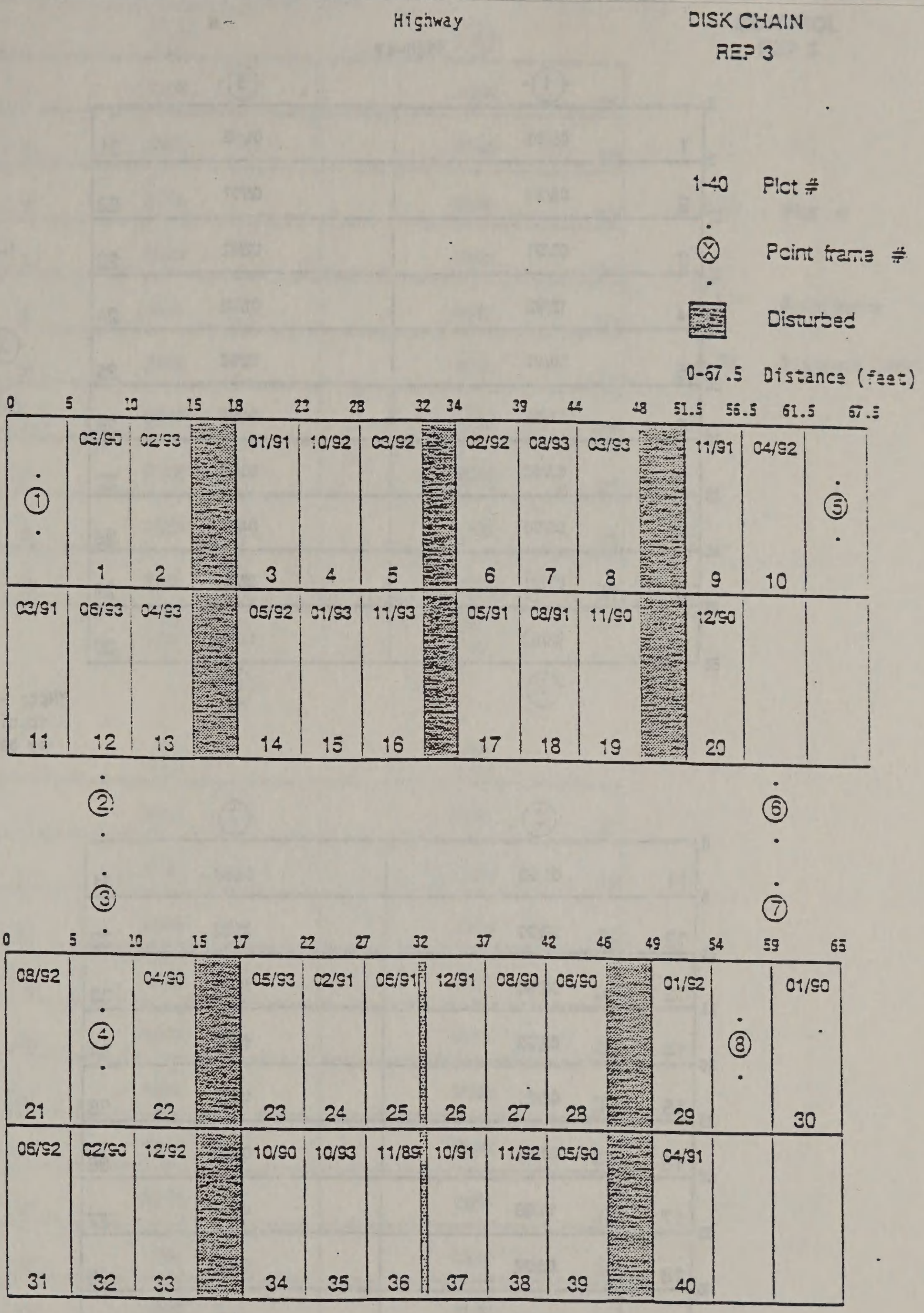
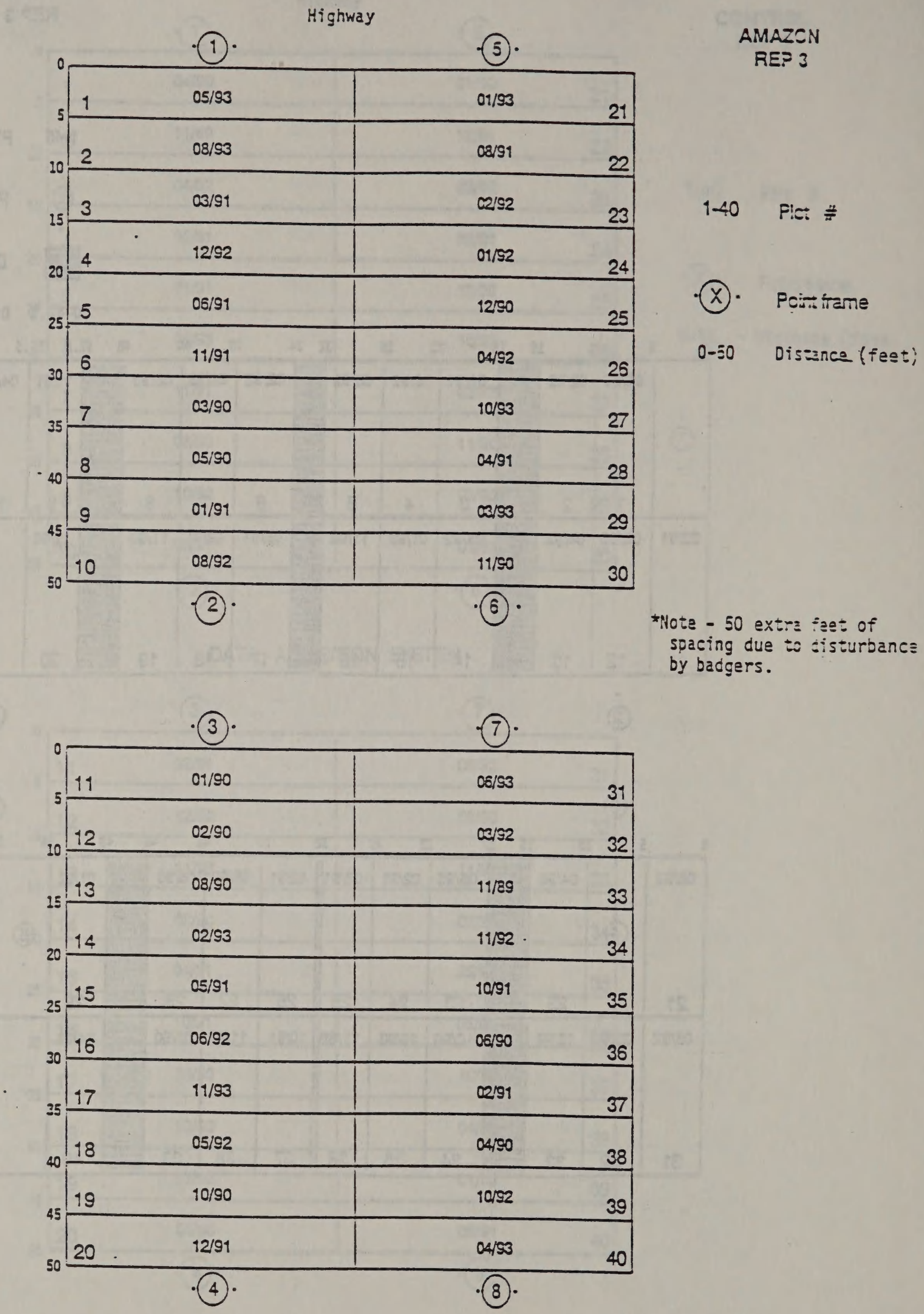


Figure 2.8 Field Layout of Sample Plots for the Disk Chain Treatment, Rep 3, at the Lockman Study Site, Mountain Home, Idaho.



1	05/93	01/93	21
2	08/93	08/91	22
3	03/91	02/92	23
4	12/92	01/92	24
5	06/91	12/90	25
6	11/91	04/92	26
7	03/90	10/93	27
8	05/90	04/91	28
9	01/91	03/93	29
10	08/92	11/90	30

*Note - 50 extra feet of spacing due to disturbance by badgers.

11	01/90	06/93	31
12	02/90	03/92	32
13	08/90	11/89	33
14	02/93	11/92	34
15	05/91	10/91	35
16	06/92	06/90	36
17	11/93	02/91	37
18	05/92	04/90	38
19	10/90	10/92	39
20	12/91	04/93	40

Figure 2.9 Field Layout of Sample Plots for the Amazon Drill Treatment, Rep 3, at the Lockman Study Site, Mountain Home, Idaho.

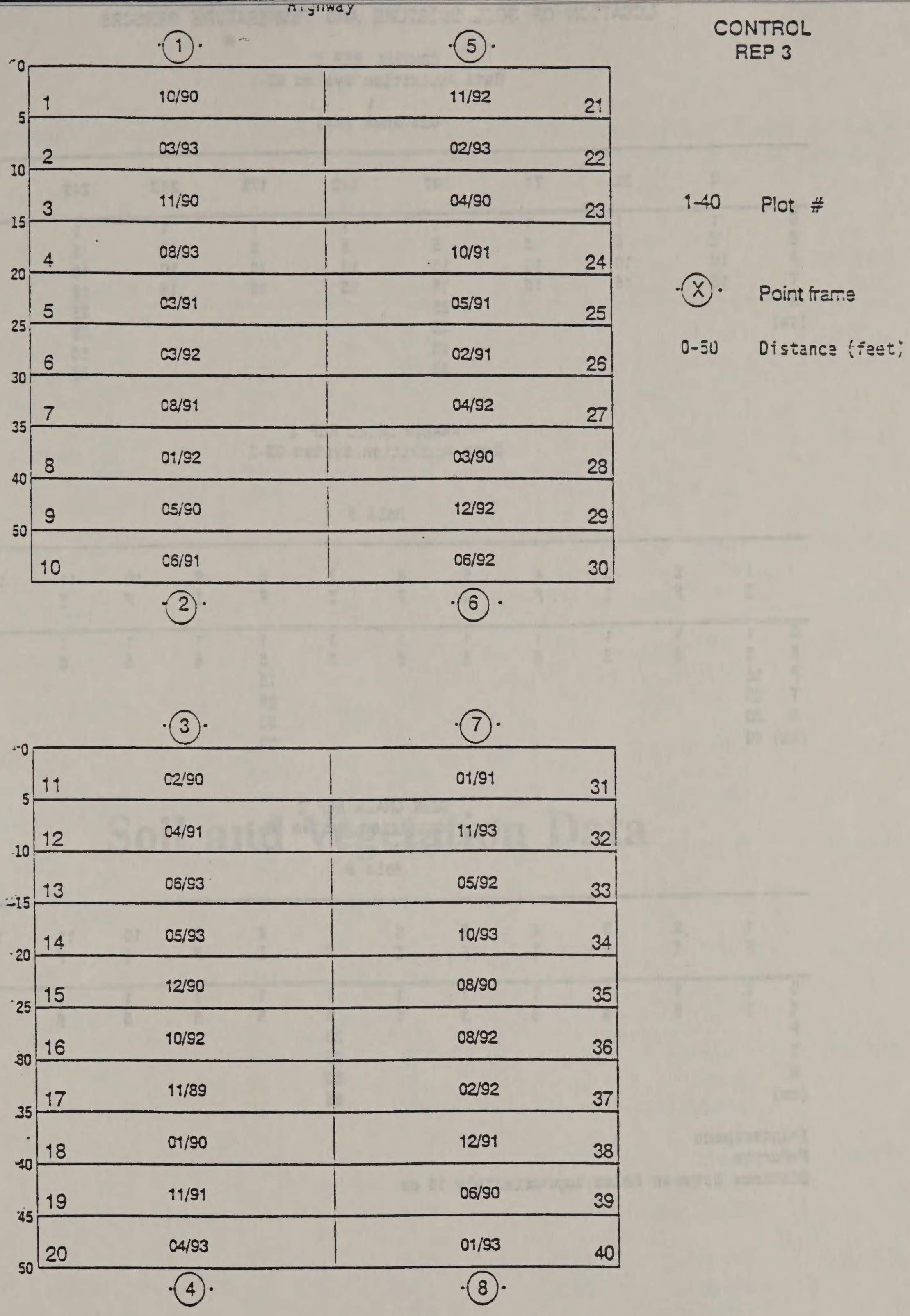


Figure 2.10 Field Layout of Sample Plots for the Control, Rep 3, at the Lockman Study Site, Mountain Home, Idaho.

LOCATION OF SOIL MOISTURE AND TEMPERATURE SENSORS

CONTROL REP 2
Data Aquisition System GS-1

Distance (cm)

	0	36	71	107	142	178	213	249
D	1	1	1	1	1	1	1	1
E	5	5	5	5	5	5	5	5
P	10	10	10	10	10	10	10	10
T	15	15	15	15	15	15	15	15
H				25				25
(cm)				35				35
				50				50
				85				85

AMAZON DRILL REP 2
Data Aquisition System GS-2

Hole #

	1 I	2 F	3 I	4 F	5 I	6 F	7 I	8 F	9 I	10 F	11 I	12 F
D	1	1	1	1	1	1	1	1	1	1	1	1
E	5	5	5	5	5	5	5	5	5	5	5	5
P	15							15				
T	25							25				
H	50							50				
(cm)	80							80				

DISK CHAIN REP 2
Data Aquisition System GS-3

Hole #

	1 F	2 I	3 F	4 I	5 F	6 I	7 F	8 I	9 F	10 I	11 F	12 I
D	1	1	1	1	1	1	1	1	1	1	1	1
E	5	5	5	5	5	5	5	5	5	5	5	5
P							25					
T							35					
H							50					
(cm)							85					

I=Interspace
F=Furrow
Distance between holes approximately 18 cm

Figure 2.11 Locations and Depths of Soil Water and Temperature Sensors for each Treatment at the Lockman Study Site, Mountain Home, Idaho.

Soil and Vegetation Data

Table 2.1. Organic Carbon Content (%) by Replication (Rep) and Date of the Permenant Transects. Lockman Study Site, Mountain Home, Idaho. Composite soil sample of 10/rep.

Sample Date	Treatment	Organic Carbon (%) Rep 1	Rep 2	Rep 3	Average of Reps
11/20/89	Control	1.55	1.79	1.63	1.65
	Amazon	1.53	2.08	1.50	1.70
	Disk Chain	0.91	0.65	1.24	0.94
10/04/90	Control	1.57	1.04	1.19	1.27
	Amazon	1.47	1.56	1.14	1.39
	Disk Chain	0.97	1.14	0.82	0.98
11/05/90	Control	1.78	0.82	0.72	1.11
	Amazon	1.30	2.48	1.18	1.66
	Disk Chain	1.25	0.94	1.27	1.16
12/03/90	Control	1.45	1.57	1.01	1.35
	Amazon	1.40	2.60	0.94	1.65
	Disk Chain	1.16	0.64	0.81	0.87
01/05/91	Control	1.18	1.76	1.74	1.56
	Amazon	1.43	1.54	1.08	1.35
	Disk Chain	0.56	0.80	1.51	0.95
02/01/91	Control	1.87	1.23	1.37	1.49
	Amazon	1.88	2.15	1.74	1.92
	Disk Chain	0.99	0.79	1.26	1.01
03/05/91	Control	1.48	1.42	1.04	1.31
	Amazon	0.68	0.74	0.50	0.64
	Disk Chain	1.09	0.83	1.05	0.99
03/29/91	Control	1.02	0.85	1.66	1.18
	Amazon	0.93	1.38	1.35	1.22
	Disk Chain	0.74	1.22	1.32	1.10
05/01/91	Control	1.63	1.24	0.85	1.24
	Amazon	1.73	1.88	1.15	1.59
	Disk Chain	1.02	0.93	0.97	0.97
06/03/91	Control	1.16	0.86	1.31	1.11
	Amazon	2.08	4.18	0.95	2.40
	Disk Chain	1.29	0.80	1.18	1.09
08/01/91	Control	0.70	1.23	0.76	0.89
	Amazon	1.39	1.22	1.07	1.23
	Disk Chain	1.07	0.88	1.15	1.03
10/01/91	Control	0.82	1.10	0.74	0.88
	Amazon	1.27	1.12	1.06	1.15
	Disk Chain	0.91	0.50	1.00	0.80

Table 2.1 Cont.

Sample Date	Treatment	Rep 1	Rep 2	Rep 3	Average of Reps
11/05/91	Control	0.69	1.15	0.94	0.93
	Amazon	0.76	2.17	1.68	1.53
	Disk Chain	0.71	0.97	1.17	0.95
12/06/91	Control	1.31	1.77	1.38	1.49
	Amazon	1.25	1.34	0.90	1.16
	Disk Chain	1.24	0.61	0.79	0.88
01/02/92	Control	1.75	0.89	1.23	1.29
	Amazon	2.13	3.08	1.56	2.26
	Disk Chain	1.19	0.94	0.95	1.03
02/01/92	Control	1.05	0.80	0.78	0.88
	Amazon	1.47	1.36	1.23	1.36
	Disk Chain	0.81	0.80	1.31	0.97
03/05/92	Control	0.65	1.12	0.91	0.89
	Amazon	1.17	1.71	1.32	1.40
	Disk Chain	1.14	0.94	1.20	1.09
04/02/92	Control	0.94	0.95	1.05	0.98
	Amazon	1.77	1.23	0.76	1.25
	Disk Chain	0.99	0.85	1.05	0.96
05/08/92	Control	0.69	0.83	1.09	0.87
	Amazon	1.29	1.05	1.00	1.11
	Disk Chain	1.09	0.73	0.93	0.92
06/02/92	Control	0.97	1.16	0.97	1.03
	Amazon	1.45	2.36	1.77	1.86
	Disk Chain	1.01	0.62	1.19	0.94

Table 2.2. Particle-Size Distribution (%), Textural Classification and % Rock of Permanent Transects by Replication (Rep). Sampled 1989-1992. Lockman Study Site, Mountain Home, Idaho.
n = composite of 10 sampled/rep.

Distribution (%)

Sampled November 20-21, 1989

Treatment		Rep 1	Rep 2	Rep 3	Average of Reps
Control	Rocks	3.11	7.14	2.93	4.40
	Sand	31.03	41.93	41.93	38.30
	Silt	55.29	48.91	46.06	50.09
	Clay	13.68	9.16	12.01	11.62
	Classification	Silt Loam	Loam	Loam	Loam-Silt Loam
Amazon	Rocks	3.77	7.25	1.86	4.29
	Sand	38.22	39.03	35.40	37.55
	Silt	52.45	51.15	52.68	52.09
	Clay	9.33	9.82	11.92	10.35
	Classification	Silt Loam	Silt Loam	Silt Loam	Silt Loam
Disk Chain	Rocks	5.26	6.72	3.92	5.30
	Sand	36.74	42.82	39.55	39.70
	Silt	49.64	48.42	45.94	48.00
	Clay	13.62	8.76	14.51	12.30
	Classification	Loam	Loam	Loam	Loam

Sampled October 4, 1990

Treatment		Rep 1	Rep 2	Rep 3	Average of Reps
Control	Rocks	2.69	9.54	9.84	7.35
	Sand	35.85	38.18	38.73	37.59
	Silt	52.27	49.03	53.73	51.68
	Clay	11.88	12.78	7.54	10.73
	Classification	Silt Loam	Loam	Silt Loam	Silt Loam
Amazon	Rocks	4.02	9.11	3.00	5.38
	Sand	36.13	41.40	38.05	38.53
	Silt	51.97	48.44	48.09	49.50
	Clay	11.89	10.16	13.87	11.97
	Classification	Silt Loam	Loam	Loam	Loam

Table 2.2 Cont.

Disk Chain	Rocks	3.84	8.05	3.14	5.01
	Sand	42.50	45.98	36.18	41.56
	Silt	45.33	42.33	49.79	45.82
	Clay	12.17	11.69	14.03	12.63
Classification		Loam	Loam	Loam	Loam

Sampled November 5, 1990

Treatment		Rep 1	Rep 2	Rep 3	Average of Reps
Control	Rocks	3.75	14.50	3.68	7.31
	Sand	29.85	41.63	42.87	38.12
	Silt	52.29	51.64	53.87	52.60
	Clay	17.87	6.73	3.25	9.28
Classification		Silt Loam	Silt Loam	Silt Loam	Silt Loam
Amazon	Rocks	3.26	3.42	4.09	3.59
	Sand	34.13	31.47	42.24	35.95
	Silt	56.04	55.92	50.36	54.11
	Clay	9.83	12.61	7.40	9.95
Classification		Silt Loam	Silt Loam	Silt Loam	Silt Loam
Disk Chain	Rocks	5.21	5.76	3.06	4.67
	Sand	35.20	35.19	33.46	34.62
	Silt	51.28	51.15	52.81	51.74
	Clay	13.52	13.66	13.73	13.64
Classification		Silt Loam	Silt Loam	Silt Loam	Silt Loam

Sampled December 3, 1990

Treatment		Rep 1	Rep 2	Rep 3	Average of Reps
Control	Rocks	4.13	10.89	1.78	5.60
	Sand	42.24	41.26	42.68	42.06
	Silt	49.50	50.31	47.25	49.02
	Clay	8.26	8.43	10.08	8.92
Classification		Loam	Silt Loam	Loam	Loam
Amazon	Rocks	6.27	13.25	6.60	8.71
	Sand	36.52	53.82	50.75	47.03
	Silt	54.28	38.19	46.50	46.32
	Clay	9.20	7.99	2.75	6.65
Classification		Silt Loam	Loam	Loam	Loam

Table 2.2 Cont.

Disk Chain	Rocks	16.55	6.56	3.02	8.71
	Sand	34.23	42.69	33.82	36.91
	Silt	48.31	49.23	53.41	50.32
	Clay	17.47	8.08	12.77	12.77
	Classification	Loam	Loam	Silt Loam	Silt Loam

Sampled January 5, 1991

Treatment		Rep 1	Rep 2	Rep 3	Average of Reps
Control	Rocks	3.29	11.25	2.25	5.60
	Sand	39.61	41.50	30.76	37.29
	Silt	52.72	51.14	55.16	53.01
	Clay	7.67	7.36	14.08	9.70
	Classification	Silt Loam	Silt Loam	Silt Loam	Silt Loam
Amazon	Rocks	11.06	4.13	9.13	8.11
	Sand	39.12	43.88	40.77	41.26
	Silt	51.72	47.33	51.40	50.15
	Clay	9.16	8.79	7.84	8.59
	Classification	Silt Loam	Loam	Silt Loam	Silt Loam
Disk Chain	Rocks	16.06	3.97	2.84	7.62
	Sand	32.42	37.59	35.28	35.10
	Silt	48.95	50.74	48.40	49.37
	Clay	18.62	11.67	16.32	15.53
	Classification	Loam	Silt Loam	Loam	Loam

Sampled February 1, 1991

Treatment		Rep 1	Rep 2	Rep 3	Average of Reps
Control	Rocks	1.44	6.78	6.68	4.97
	Sand	33.38	38.13	46.75	39.42
	Silt	57.43	50.56	46.17	51.39
	Clay	9.19	11.30	7.08	9.19
	Classification	Silt Loam	Silt Loam	Loam	Silt Loam
Amazon	Rocks	4.36	10.97	3.13	6.15
	Sand	38.62	47.87	38.21	41.57
	Silt	52.64	41.60	49.05	47.76
	Clay	8.74	10.52	12.74	10.67
	Classification	Silt Loam	Loam	Loam	Loam

Table 2.2 Cont.

Disk Chain	Rocks	2.39	6.52	3.00	3.97
	Sand	38.84	44.74	37.18	40.25
	Silt	47.25	48.05	51.98	49.10
	Clay	13.91	7.21	10.84	10.65
	Classification	Loam	Loam	Silt Loam	Loam

Sampled March 5, 1991

Treatment		Rep 1	Rep 2	Rep 3	Average of Reps
Control	Rocks	4.17	9.64	6.04	6.62
	Sand	40.58	43.06	42.09	41.91
	Silt	49.73	50.05	46.45	48.74
	Clay	9.68	6.89	11.46	9.35
	Classification	Loam	Loam-Silt Loam	Loam	Loam
Amazon	Rocks	6.89	15.62	10.57	11.03
	Sand	38.87	42.93	36.41	39.41
	Silt	51.63	37.74	46.10	45.16
	Clay	9.49	19.33	17.49	15.44
	Classification	Silt Loam	Loam	Loam	Loam
Disk Chain	Rocks	11.42	17.03	3.69	10.71
	Sand	38.14	46.55	40.12	41.60
	Silt	47.06	37.20	43.84	42.70
	Clay	14.80	16.25	16.05	15.70
	Classification	Loam	Loam	Loam	Loam

Sampled March 29, 1991

Treatment		Rep 1	Rep 2	Rep 3	Average of Reps
Control	Rocks	3.95	9.37	2.22	5.18
	Sand	43.03	45.07	35.65	41.25
	Silt	47.04	51.90	52.75	50.56
	Clay	9.93	3.03	11.60	8.19
	Classification	Loam	Silt Loam	Silt Loam	Loam-Silt Loam
Amazon	Rocks	3.53	2.91	3.30	3.25
	Sand	37.04	44.80	31.11	37.65
	Silt	55.31	47.82	58.53	53.88
	Clay	7.65	7.39	10.36	8.47
	Classification	Silt Loam	Loam	Silt Loam	Silt Loam

Table 2.2 Cont.

Disk Chain	Rocks	9.14	3.13	3.92	5.39
	Sand	36.70	38.88	37.59	37.72
	Silt	55.43	42.73	47.37	48.51
	Clay	7.87	18.39	15.04	13.77
	Classification	Silt Loam	Loam	Loam	Loam

Sampled May 1, 1991

Treatment		Rep 1	Rep 2	Rep 3	Average of Reps
Control	Rocks	6.97	6.48	11.27	8.24
	Sand	34.43	39.26	47.38	40.36
	Silt	57.21	53.74	49.10	53.35
	Clay	8.36	7.00	3.51	6.29
	Classification	Silt Loam	Silt Loam	Loam	Silt Loam
Amazon	Rocks	5.19	6.95	7.49	6.55
	Sand	40.28	49.93	45.43	45.21
	Silt	50.24	40.87	46.04	45.71
	Clay	9.48	9.21	8.53	9.07
	Classification	Loam-Silt Loam	Loam	Loam	Loam
Disk Chain	Rocks	7.10	8.05	4.50	6.55
	Sand	38.04	42.29	34.83	38.38
	Silt	52.71	39.31	49.93	47.32
	Clay	9.25	18.41	15.24	14.30
	Classification	Silt Loam	Loam	Loam	Loam

Sampled June 3, 1991

Treatment		Rep 1	Rep 2	Rep 3	Average of Reps
Control	Rocks	3.92	7.48	2.77	4.72
	Sand	31.54	37.09	35.52	34.72
	Silt	55.62	51.78	48.79	52.06
	Clay	12.83	11.13	15.69	13.22
	Classification	Silt Loam	Silt Loam	Loam	Silt Loam
Amazon	Rocks	3.87	3.02	14.63	7.17
	Sand	36.61	41.40	50.42	42.81
	Silt	49.23	45.81	39.94	44.99
	Clay	14.16	12.79	9.64	12.20
	Classification	Loam	Loam	Loam	Loam

Table 2.2 Cont.

Disk Chain	Rocks	5.38	5.42	5.96	5.58
	Sand	33.52	52.79	40.04	42.12
	Silt	53.65	35.10	46.14	44.96
	Clay	12.83	12.11	13.82	12.92
	Classification	Silt Loam	Loam-Sandy Loam	Loam	Loam

Sampled August 1, 1991

Treatment		Rep 1	Rep 2	Rep 3	Average of Reps
Control	Rocks	1.13	16.49	3.87	7.16
	Sand	33.89	42.53	38.16	38.20
	Silt	60.23	46.35	52.78	53.12
	Clay	5.88	11.11	9.06	8.68
	Classification	Silt Loam	Loam	Silt Loam	Silt Loam
Amazon	Rocks	6.81	4.04	10.48	7.11
	Sand	41.81	43.30	50.53	45.21
	Silt	51.42	50.15	44.94	48.84
	Clay	6.77	6.55	4.53	5.95
	Classification	Silt Loam	Loam- Silt Loam	Sandy Loam Silt Loam	Loam- Sandy Loam
Disk Chain	Rocks	8.69	7.28	1.62	5.86
	Sand	38.50	50.03	30.45	39.66
	Silt	52.60	39.88	51.49	47.99
	Clay	8.90	10.09	18.06	12.35
	Classification	Silt Loam	Loam	Silt Loam	Loam

Sampled October 1, 1991

Treatment		Rep 1	Rep 2	Rep 3	Average of Reps
Control	Rocks	5.52	7.18	9.75	7.49
	Sand	35.4	37.3	34.11	35.6
	Silt	60.12	57.64	59.29	59.01
	Clay	4.49	5.06	6.6	5.38
	Classification	Silt Loam	Silt Loam	Silt Loam	Silt Loam
Amazon	Rocks	6.95	8.64	1.73	5.78
	Sand	39.7	44.51	36.09	40.1
	Silt	53.71	50.31	54.03	52.68
	Clay	6.59	5.18	9.88	7.22
	Classification	Silt Loam	Sandy Loam Silt Loam	Silt Loam	Loam

Table 2.2 Cont.

Disk Chain	Rocks	4.52	8.49	4.78	5.93
	Sand	39.91	45.75	37.69	41.12
	Silt	53.77	51.39	47.45	50.87
	Clay	6.32	2.85	14.86	8.01
	Classification	Silt Loam	Silt Loam	Loam	Silt Loam

Sampled November 5, 1991

Treatment		Rep 1	Rep 2	Rep 3	Average of Reps
Control	Rocks	4.84	15.76	4.44	8.35
	Sand	34.97	43.21	39.75	39.31
	Silt	59.33	47.34	47.06	51.24
	Clay	5.7	9.45	13.2	9.45
	Classification	Silt Loam	Loam	Loam	Silt Loam
Amazon	Rocks	3.03	6.98	11.94	7.32
	Sand	38.45	46.76	45.16	43.46
	Silt	54.96	42.69	46.47	48.04
	Clay	6.6	10.55	8.37	8.51
	Classification	Silt Loam	Loam	Loam	Loam
Disk Chain	Rocks	2.72	6.84	2.84	4.13
	Sand	26.42	45.49	32.32	34.74
	Silt	68.28	40.4	50.15	52.95
	Clay	5.29	14.11	17.53	12.31
	Classification	Silt Loam	Loam	Loam	Silt Loam

Sampled December 6, 1991

Treatment		Rep 1	Rep 2	Rep 3	Average of Reps
Control	Rocks	0.8	5	3.75	3.18
	Sand	38.53	45.99	37.65	40.72
	Silt	53.86	45.42	47.36	48.88
	Clay	7.61	8.6	15	10.4
	Classification	Silt Loam	Loam	Loam	Loam
Amazon	Rocks	8.64	4.69	10.06	7.79
	Sand	34.86	39.19	39.68	37.91
	Silt	47.7	50.93	43.2	47.28
	Clay	17.43	9.88	17.12	14.81
	Classification	Loam	Silt Loam	Loam	Loam

Table 2.2 Cont.

Disk Chain	Rocks	6.35	2.95	6.13	5.15
	Sand	45.93	41.56	33.55	40.35
	Silt	43.1	51.22	51.88	48.73
	Clay	10.97	7.22	14.58	10.92
	Classification	Loam	Silt Loam	Silt Loam	Loam

Sampled January 2, 1992

Treatment		Rep 1	Rep 2	Rep 3	Average of Reps
Control	Rocks	6.71	19.8	5.74	10.75
	Sand	39.52	42.91	34.25	38.89
	Silt	45.83	46.55	52.58	48.32
	Clay	14.65	10.54	13.17	12.79
	Classification	Loam	Loam	Silt Loam	Loam
Amazon	Rocks	5.22	5.59	9.42	6.74
	Sand	34.64	49.36	46.34	43.45
	Silt	50.55	39.59	44.41	44.85
	Clay	14.82	11.04	9.25	11.7
	Classification	Loam - Silt Loam	Loam	Loam	Loam
Disk Chain	Rocks	4.67	4.57	3.65	4.3
	Sand	40.14	39.18	41.46	40.26
	Silt	46.18	48.75	44.53	46.49
	Clay	13.68	12.07	14.01	13.25
	Classification	Loam	Loam	Loam	Loam

Sampled February 1, 1992

Treatment		Rep 1	Rep 2	Rep 3	Average of Reps
Control	Rocks	7.2	13.94	4.61	8.59
	Sand	34.86	35.36	31.64	33.96
	Silt	52.82	47.2	42.64	47.55
	Clay	12.32	17.44	25.71	18.49
	Classification	Silt Loam	Loam	Loam	Loam
Amazon	Rocks	4.97	6.15	8.82	6.64
	Sand	34	44.88	48.88	42.59
	Silt	55.22	39.08	42.95	45.75
	Clay	10.78	16.03	8.17	11.66
	Classification	Silt Loam	Loam	Loam	Loam

Table 2.2 Cont.

Disk Chain	Rocks	19.12	6.51	3.11	9.58
	Sand	39.06	44.75	28.76	37.52
	Silt	45.45	39.2	51.87	45.5
	Clay	15.5	16.05	19.38	16.97
	Classification	Loam	Loam	Silt Loam	Loam

Sampled March 5, 1992

Treatment		Rep 1	Rep 2	Rep 2	Average of Reps
Control	Rocks	4.78	16.29	4.99	8.69
	Sand	23.42	39.95	29.96	31.11
	Silt	61.71	47.22	58.48	55.8
	Clay	14.87	12.84	11.56	13.09
	Classification	Silt Loam	Loam	Silt Loam	Silt Loam
Amazon	Rocks	4.84	11.91	4.05	6.93
	Sand	37.99	49.9	26.79	38.23
	Silt	51.16	37.31	49.47	45.98
	Clay	10.85	12.79	23.74	15.79
	Classification	Silt Loam	Loam	Loam	Loam
Disk Chain	Rocks	5.61	5.22	2.36	4.4
	Sand	32.62	47.18	28.23	36.01
	Silt	53.13	42.46	48.2	47.93
	Clay	14.25	10.35	23.57	16.06
	Classification	Silt Loam	Loam	Loam	Loam

Sampled April 2, 1992

Treatment		Rep 1	Rep 2	Rep 3	Average of Reps
Control	Rocks	5.59	4.76	9.64	6.66
	Sand	26.09	36.17	26.64	29.63
	Silt	57.44	54.12	48.84	53.47
	Clay	16.47	9.71	24.52	16.9
	Classification	Silt Loam	Silt Loam	Loam	Silt Loam
Amazon	Rocks	3.03	6.04	12.93	7.34
	Sand	27.73	34.03	37.63	33.13
	Silt	59.21	52.94	53.74	55.29
	Clay	13.06	13.03	8.63	11.57
	Classification	Silt Loam	Silt Loam	Silt Loam	Silt Loam

Table 2.2 Cont.

Disk Chain	Rocks	4.28	20.13	2.46	8.95
	Sand	36.23	40.1	24.15	33.49
	Silt	51.33	48.87	56.33	52.18
	Clay	12.44	11.03	19.52	14.33
	Classification	Silt Loam	Loam	Silt Loam	Silt Loam

Sampled May 8, 1992

Treatment		Rep 1	Rep 2	Rep 3	Average of Reps
Control	Rocks	3.13	12.92	1.75	5.93
	Sand	28.13	36.54	31.39	32.02
	Silt	57.11	43	48.47	49.53
	Clay	14.76	20.46	20.14	18.45
	Classification	Silt Loam	Loam	Loam	Loam - Silt Loam
Amazon	Rocks	4.08	10.81	2.73	5.88
	Sand	28.83	40.74	37.79	35.78
	Silt	56.54	45.34	44.01	48.63
	Clay	14.63	13.92	18.2	15.58
	Classification	Silt Loam	Loam	Loam	Loam
Disk Chain	Rocks	9.21	8.71	3.3	7.07
	Sand	35.6	35.19	31.88	34.22
	Silt	51.05	50.47	46.96	49.49
	Clay	13.35	14.34	21.16	16.28
	Classification	Silt Loam	Silt Loam	Loam	Loam

Sampled June 2, 1992

Treatment		Rep 1	Rep 2	Rep 3	Average of Reps
Control	Rocks	3.44	5.47	3.24	4.05
	Sand	33.4	32.25	38.38	34.67
	Silt	52.34	56.71	47.87	52.31
	Clay	14.26	11.04	13.75	13.02
	Classification	Silt Loam	Silt Loam	Loam	Silt Loam
Amazon	Rocks	5.99	5.03	8.62	6.55
	Sand	33.97	31.85	30.42	32.08
	Silt	53.16	51.3	52.22	52.23
	Clay	12.87	16.85	17.36	15.7
	Classification	Silt Loam	Silt Loam	Silt Loam	Silt Loam

Table 2.2 Cont.

Disk Chain	Rocks	5.56	10.85	2.45	6.29
	Sand	30.99	31.78	28.64	30.47
	Silt	50.37	54.15	50	51.51
	Clay	18.63	14.07	21.36	18.02
	Classification	Loam - Silt Loam	Silt Loam	Loam - Silt Loam	Silt Loam

Table 2.3. Post-treatment Mean Surface Roughness (cm)* by Treatment of Permanent Transects. Lockman Study Site, Mountain Home, Idaho.

	Treatment		
	Control	Amazon	Disk Chain
November 1989	1.07	1.96	2.08
June 1990	1.09	1.74	1.97
June 1991	1.16	1.94	1.94
June 1992	1.34	1.79	1.77

* Mean surface roughness is the pooled standard deviation of 8 permanent transects for each treatment. Each treatment is replicated 3 times.

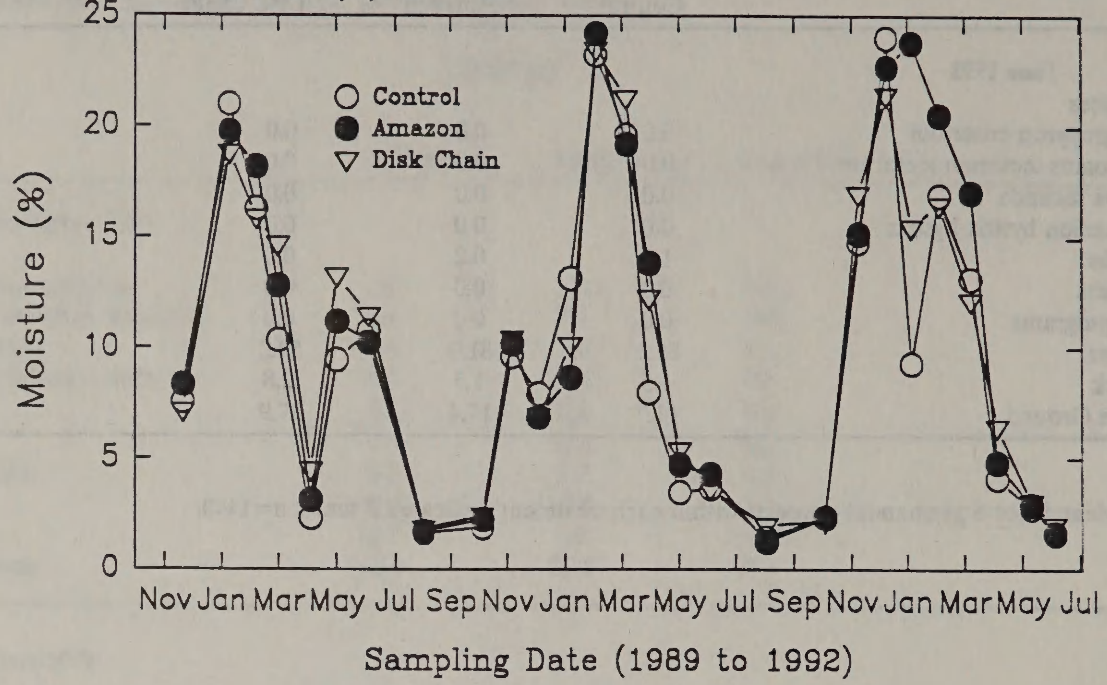
Table 2.4. Post-treatment Mean* Ground Surface Condition (%) by Treatment of Permanent Transects. Sampled 1989-1991. Lockman Study Site, Mountain Home, Idaho.

		Treatment	
	Control	Amazon	Disk Chain
November 1989			
Grasses			
Agropyron cristatum	0.0	0.0	0.0
Bromus tectorum tectorum	0.4	0.1	0.0
Poa secunda	0.4	1.0	0.1
Sitanion hystrix hystrix	0.0	0.0	0.0
Forbs	0.0	0.0	0.0
Shrubs	0.0	0.0	0.0
Cryptograms	0.2	0.0	0.0
Litter	60.4	23.5	2.0
Rock	0.7	0.0	0.0
Bare Ground	37.9	75.4	97.9
June 1990			
Grasses			
Agropyron cristatum	0.0	1.4	1.4
Bromus tectorum tectorum	42.2	49.0	21.8
Poa secunda	2.1	3.7	0.4
Sitanion hystrix hystrix	0.1	0.5	23.6
Forbs	7.1	3.2	12.7
Shrubs	0.0	0.0	0.0
Cryptograms	2.3	0.0	0.0
Litter	16.0	6.8	0.8
Rock	0.8	0.3	0.6
Bare Ground	29.4	35.1	62.3
June 1991			
Grasses			
Agropyron cristatum	0.0	0.8	1.9
Bromus tectorum tectorum	45.4	47.4	33.5
Poa secunda	2.6	4.7	0.4
Sitanion hystrix hystrix	0.4	0.8	0.0
Forbs	4.9	4.4	11.8
Shrubs	0.0	0.0	0.0
Cryptograms	0.3	0.0	0.0
Litter	24.1	21.1	6.8
Rock	0.9	0.3	0.6
Bare Ground	21.4	20.5	45.0

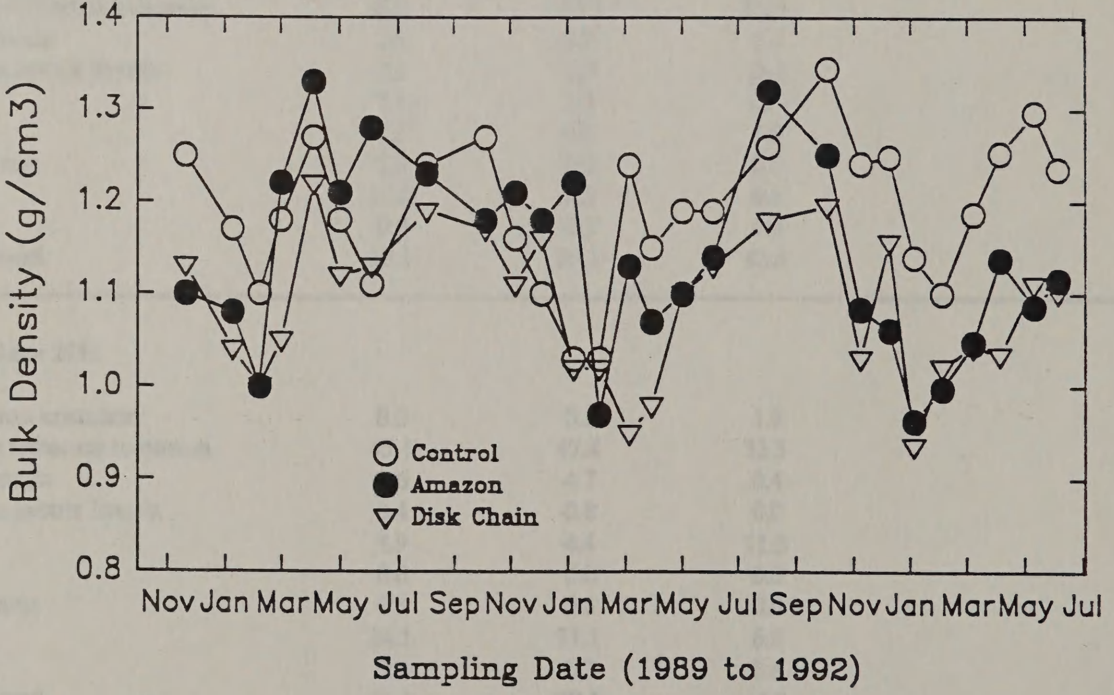
Table 2.4 Cont.

	Control	Amazon	Disk Chain
June 1992			
Grasses			
Agropyron cristatum	0.0	0.0	0.0
Bromus tectorum tectorum	0.0	0.0	0.0
Poa secunda	0.0	0.0	0.0
Sitanion hystrix hystrix	0.0	0.0	0.0
Forbs	1.5	0.2	0.0
Shrubs	0.0	0.0	0.0
Cryptograms	0.0	0.0	0.0
Litter	85.3	81.0	59.2
Rock	1.5	1.3	2.8
Bare Ground	11.7	17.4	37.9

* Mean is for 8 permanent transects within each treatment replicated 3 times, n=1440.



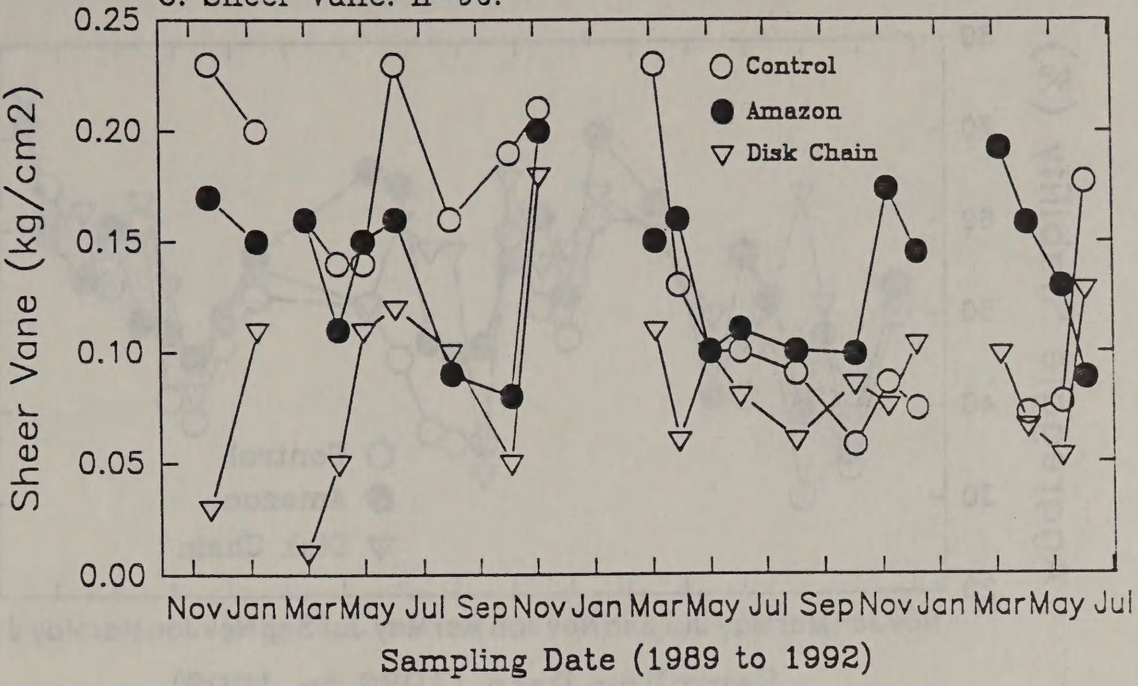
A. Moisture (%). n = 30.



B. Bulk Density. n=30.

Fig. 2.12 (A-D) Moisture, Bulk Density, Sheer Vane, and Penetrometer by Sampling Date (1989 to 1992). Greenstripping, Permanent Transects.

C. Sheer Vane. n=90.



D. Penetrometer. n=90.

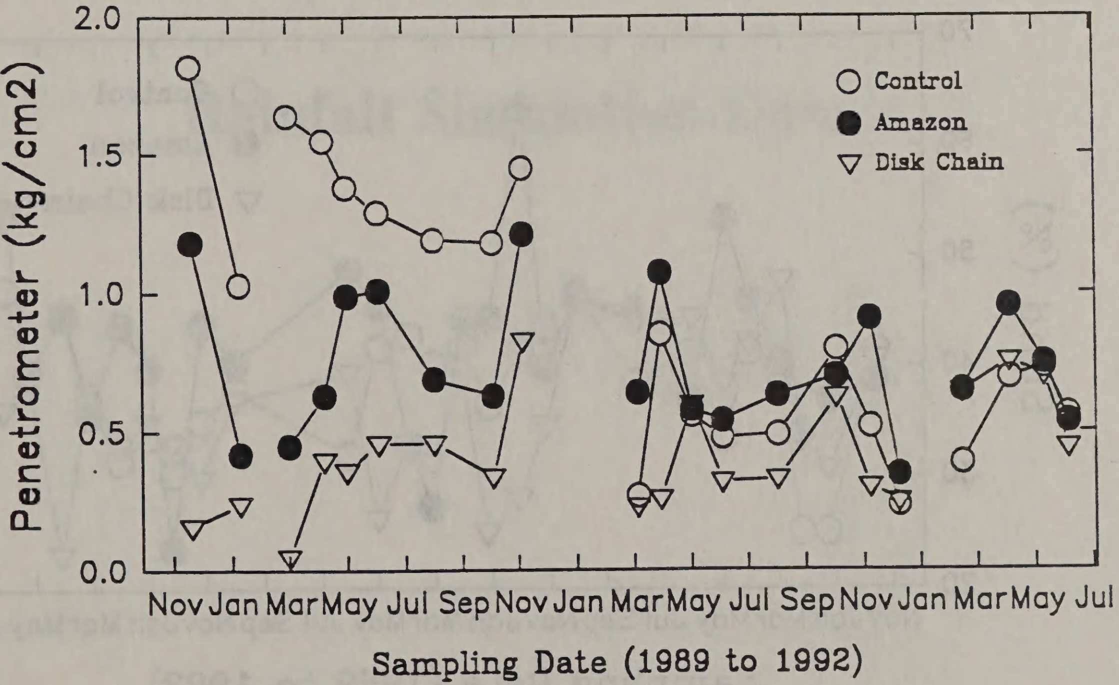


Fig. 2.12 (A-D) Continued

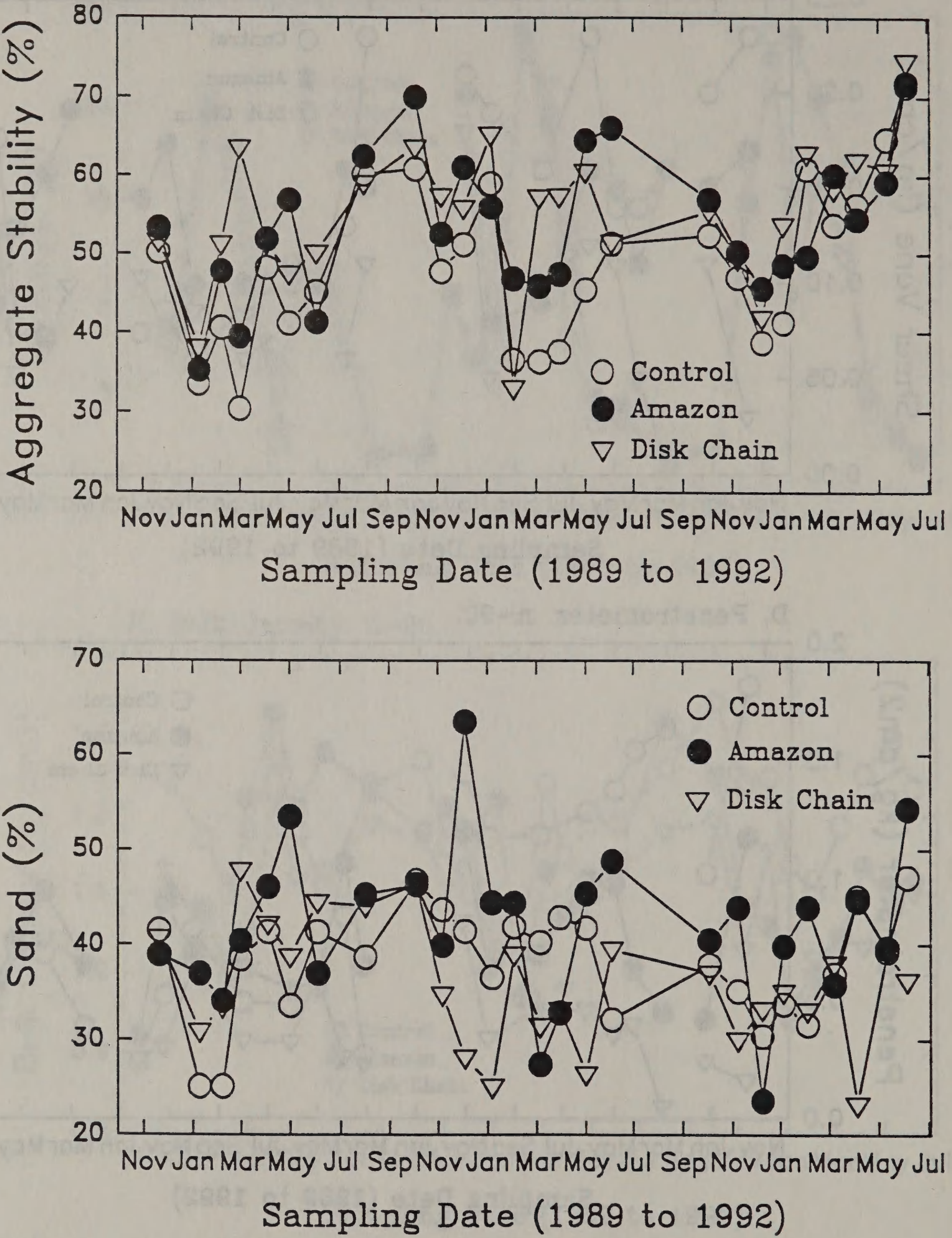


Fig. 2.13 Aggregate Stability (top) and % Sand of Aggregate Stability (bottom) Samples by Sampling Date (1989 to 1992). Greenstripping, Permanent Transects. n=10/rep. Rep=3.

Rainfall Simulation Data

Table 2.5. Organic Carbon by Replication (Rep) of Rainfall Simulation plots. Lockman Study Site, Mountain Home, Idaho.

		Organic Carbon (%)			
Sample Date	Treatment	Rep 1	Rep 2	Rep 3	Average of Reps
June/ July 1990*	Control	1.11	1.30	1.41	1.29
	Amazon	2.18	1.18	1.48	1.62
	Disk Chain	1.15	0.97	0.91	1.01
June 1991**	Control	1.61	1.24	1.59	1.48
	Amazon	1.48	1.40	1.26	1.38
	Disk Chain	1.02	1.27	1.56	1.28
June 1992**	Control	0.66	0.87	0.74	0.75
	Amazon	0.81	1.07	1.00	0.96
	Disk Chain	0.89	1.39	1.06	1.11

* n=4/rep

** n=2/rep (each a composite of 4 samples/rep)

Table 2.6. Particle-Size Distribution, Textural Classification and % Rock by Replication (Rep) of Rainfall Simulation Plots. Sampled 1990 and 1991. Lockman Study Site, Mountain Home, ID.

		Distribution (%)			
Treatment	Particle Size	Rep 1	Rep 2	Rep 3	Average of Reps
Sampled June-July 1990*					
Control	% Rocks	1.88	3.38	3.40	2.89
	% Sand	37.99	42.71	33.43	38.04
	% Silt	54.51	46.97	55.02	52.17
	% Clay	7.51	10.32	11.55	9.80
Classification		Silt Loam	Loam	Silt Loam	Silt Loam
Amazon	% Rocks	4.38	1.90	1.80	2.69
	% Sand	39.77	36.46	32.11	36.11
	% Silt	51.68	55.14	57.74	54.85
	% Clay	8.55	8.41	10.15	9.04
Classification		Silt Loam	Silt Loam	Silt Loam	Silt Loam
Disk Chain	% Rocks	10.74	4.71	2.23	5.89
	% Sand	41.56	6.63	31.64	36.61
	% Silt	44.09	52.37	52.87	49.78
	% Clay	14.35	11.00	15.49	13.61
Classification		Loam	Silt Loam	Silt Loam	Loam-Silt Loam
* n=4/rep					
Sampled June, 1991**					
Control	% Rocks	3.58	7.77	3.77	5.04
	% Sand	44.68	48.15	39.12	43.98
	% Silt	46.50	44.02	45.56	45.36
	% Clay	8.82	7.83	15.31	10.65
Classification		Loam	Loam	Loam	Loam
Amazon	% Rocks	8.69	6.61	4.13	6.47
	% Sand	43.01	38.22	38.82	40.02
	% Silt	49.72	55.80	45.70	50.41
	% Clay	7.27	5.98	15.48	9.58
Classification		Loam	Silt Loam	Loam	Loam-Silt Loam
Disk Chain	% Rocks	2.55	3.42	4.45	3.47
	% Sand	45.89	40.49	31.99	39.46
	% Silt	45.60	48.47	49.66	47.91
	% Clay	8.52	11.04	18.35	12.63
Classification		Loam	Loam	Loam	Loam

** n=2/rep (each a composite of 4 samples)

Table 2.6 Cont.

Treatment	Particle Size	Rep 1	Rep 2	Rep 3	Average of Reps
Sampled June, 1992**					
Control	% Rocks	4.50	2.95	3.85	3.76
	% Sand	41.31	31.76	37.75	36.94
	% Silt	47.47	56.76	51.04	51.75
	% Clay	11.23	11.47	11.22	11.31
	Classification	–	–	–	
Amazon	% Rocks	3.25	3.22	2.52	3.00
	% Sand	38.11	39.17	43.35	40.21
	% Silt	54.91	48.73	47.32	50.32
	% Clay	6.99	12.09	9.34	9.47
	Classification	–	–	–	
Disk Chain	% Rocks	3.25	3.23	2.53	3.00
	% Sand	39.29	36.58	38.98	38.28
	% Silt	51.09	49.31	48.05	49.48
	% Clay	10.30	14.11	12.97	12.46
	Classification	–	–	–	

** n=2/rep (each a composite of 4 samples)

Table 2.7. Aggregate Stability of Rainfall Simulation plots. Data is Presented by Replication for both Interspace (I) and Furrow (F) Locations. Included is the Average of the Interspaces and Furrows (avg). Sampling Times are Before (B) and After (A) Rainfall Simulation. Lockman Study Site, Mountain Home, Idaho. n=8/rep.

			Aggregate Stability (%)			
Treatment	Time of Sampling	I/F avg	Rep 1	Rep 2	Rep 3	Average of Reps
Sampled June/July 1990						
Control	B	---	58.12	64.65	70.71	64.49
Control	A	---	24.12	17.92	33.37	25.14
Amazon	B	I	57.65	58.98	61.10	59.24
		F	60.34	58.45	58.25	59.01
		avg	59.00	58.72	59.67	59.13
Amazon	A	I	26.62	29.51	30.88	29.00
		F	23.96	24.90	27.24	25.37
		avg	25.29	27.21	29.06	27.19
Disk Chain	B	I	63.86	48.29	61.20	57.78
		F	62.73	56.52	60.54	59.93
		avg	63.29	52.41	60.87	58.86
Disk Chain	A	I	59.60	34.80	41.77	45.39
		F	54.24	40.22	38.60	44.35
		avg	56.92	37.51	40.19	44.87
Sampled June 1991						
Control	B	---	57.72	68.32	70.55	65.53
Control	A	---	26.77	32.07	54.55	37.79
Amazon	B	I	63.01	55.25	66.42	61.56
		F	51.17	64.28	66.78	60.74
		avg	57.09	59.77	66.60	61.15
Amazon	A	I	40.75	30.09	39.89	36.91
		F	35.29	31.59	46.40	37.76
		avg	38.02	30.84	43.15	37.34
Disk Chain	B	I	48.38	58.57	56.20	54.38
		F	55.81	63.38	69.40	62.86
		avg	52.09	60.97	62.80	58.62
Disk Chain	A	I	32.82	35.50	57.44	41.92
		F	33.16	43.25	46.35	40.92
		avg	32.99	39.37	51.90	41.42

Table 2.7 Cont.

Treatment	Time of Sampling	I/F avg	Rep 1	Rep 2	Rep 3	Average of Reps
Sampled June 1992						
Control	B	—	44.83	54.99	52.86	50.89
Control	A	—	33.69	35.62	35.32	34.86
Amazon	B	I	35.35	40.43	37.91	37.89
		F	41.73	41.54	42.87	42.05
		avg	38.54	40.98	40.39	39.97
Amazon	A	I	18.78	39.31	26.56	28.22
		F	23.04	39.99	35.42	32.82
		avg	20.91	39.65	30.99	30.52
Disk Chain	B	I	41.32	82.18	45.50	56.33
		F	43.58	69.60	51.60	54.93
		avg	42.45	65.26	48.55	52.09
Disk Chain	A	I	33.72	60.97	38.20	44.30
		F	34.47	56.39	37.95	42.94
		avg	34.10	58.68	38.07	43.62

Table 2.8. Root Weight by Replication (Rep) of Rainfall Simulation plots. Lockman Study Site, Mountain Home, ID. n=4/rep.

	Root Weight (g/cm^3 on an ash free wt)			
Treatment	Rep 1	Rep 2	Rep 3	Average of Reps
Sampled June/July 1990				
Control	0.00601	0.00111	0.00110	0.00274
Amazon	0.00139	0.00124	0.00158	0.00141
Disk Chain	0.00097	0.00069	0.00044	0.00070
Sampled June 1991				
Control	0.00150	0.00205	0.00072	0.00142
Amazon	0.00128	0.00205	0.00063	0.00132
Disk Chain	0.00055	0.00126	0.00016	0.00066
Sampled June 1992				
Control	0.00093	0.00058	0.00089	0.00080
Amazon	0.00102	0.00184	0.00172	0.00153
Disk Chain	0.00187	0.00076	0.00078	0.00114

Table 2.9. Post-treatment Mean Surface Roughness (cm)* by Treatment of Rainfall Simulation Plots. Lockman Study Site, Mountain Home, Idaho.

	Treatment		
	Control	Amazon	Disk Chain
June 1990	1.08	1.13	1.49
May 1991	1.48	1.58	1.66
June 1992	1.06	1.53	1.82

* Surface roughness is the pooled standard deviation of 10 transects for each plot. Mean is determined using 2 plots within each treatment replicated 3 times, n=6.

Table 2.10. Post-treatment Mean* Ground Surface Condition (%) by Treatment of Rainfall Simulation Plots. Lockman Study Site, Mountain Home, Idaho.

	Treatment		
	Control	Amazon	Disk Chain
June 1990			
Grasses			
Agropyron cristatum	0.0	0.8	2.3
Bromus tectorum tectorum	35.0	37.9	17.7
Poa secunda	4.3	4.1	0.1
Sitanion hystrix hystrix	0.4	0.4	0.1
Forbs	2.1	2.0	7.5
Shrubs	0.0	0.0	0.0
Cryptograms	0.0	0.0	0.0
Litter	20.0	11.6	0.5
Rock	0.1	0.1	Trace
Bareground	38.1	43.1	71.8
May 1991			
Grasses			
Agropyron cristatum	0.0	1.6	4.4
Bromus tectorum tectorum	61.6	54.9	36.0
Poa secunda	3.2	3.3	0.3
Sitanion hystrix hystrix	0.6	0.7	3.1
Forbs	0.8	2.7	6.4
Shrubs	0.0	0.0	0.0
Cryptograms	0.1	0.0	0.0
Litter	20.2	17.7	8.4
Rock	0.3	0.5	0.6
Bareground	13.2	18.6	40.8

Table 2.10 Continued

	Control	Treatment Amazon	Disk Chain
June 1992			
Grasses			
Agropyron cristatum	0.0	0.0	0.0
Bromus tectorum tectorum	0.0	0.0	0.0
Poa secunda	0.0	0.0	0.0
Sitanion hystrix hystrix	0.0	0.0	0.0
Forbs	2.1	0.1	0.0
Shrubs	0.0	0.0	0.0
Cryptograms	0.0	0.0	0.0
Litter	75.2	63.8	60.7
Rock	1.0	2.7	1.8
Bareground	21.7	33.4	37.5

* Mean is for 10 transects for each of 2 plots for each treatment replicated 3 times, n=3600.

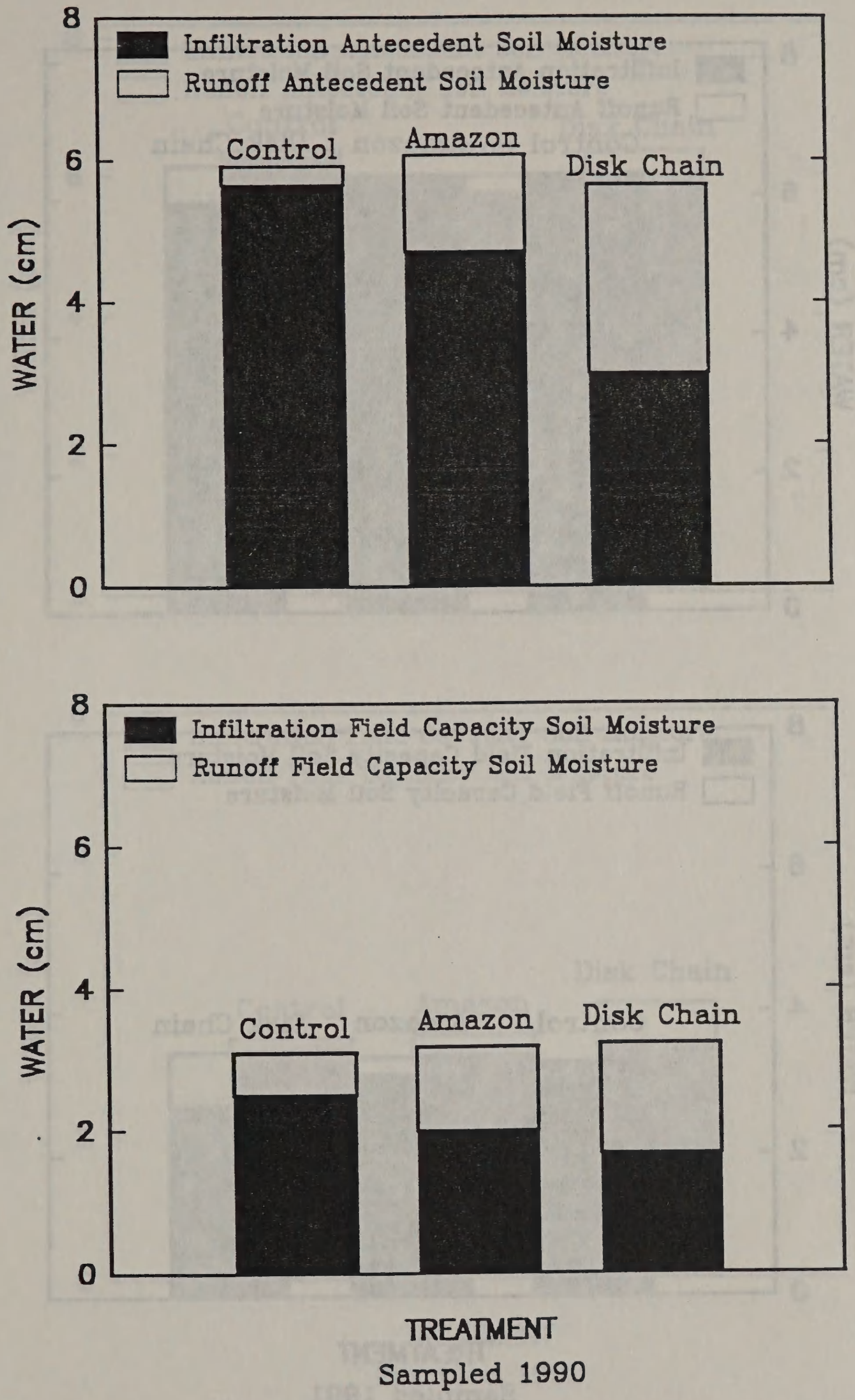


Figure 2.14 Post-treatment mean infiltration and runoff for antecedent and field capacity soil moisture conditions. Sampled 1990-1992. Lockman Study Site, Mountain Home, Idaho.

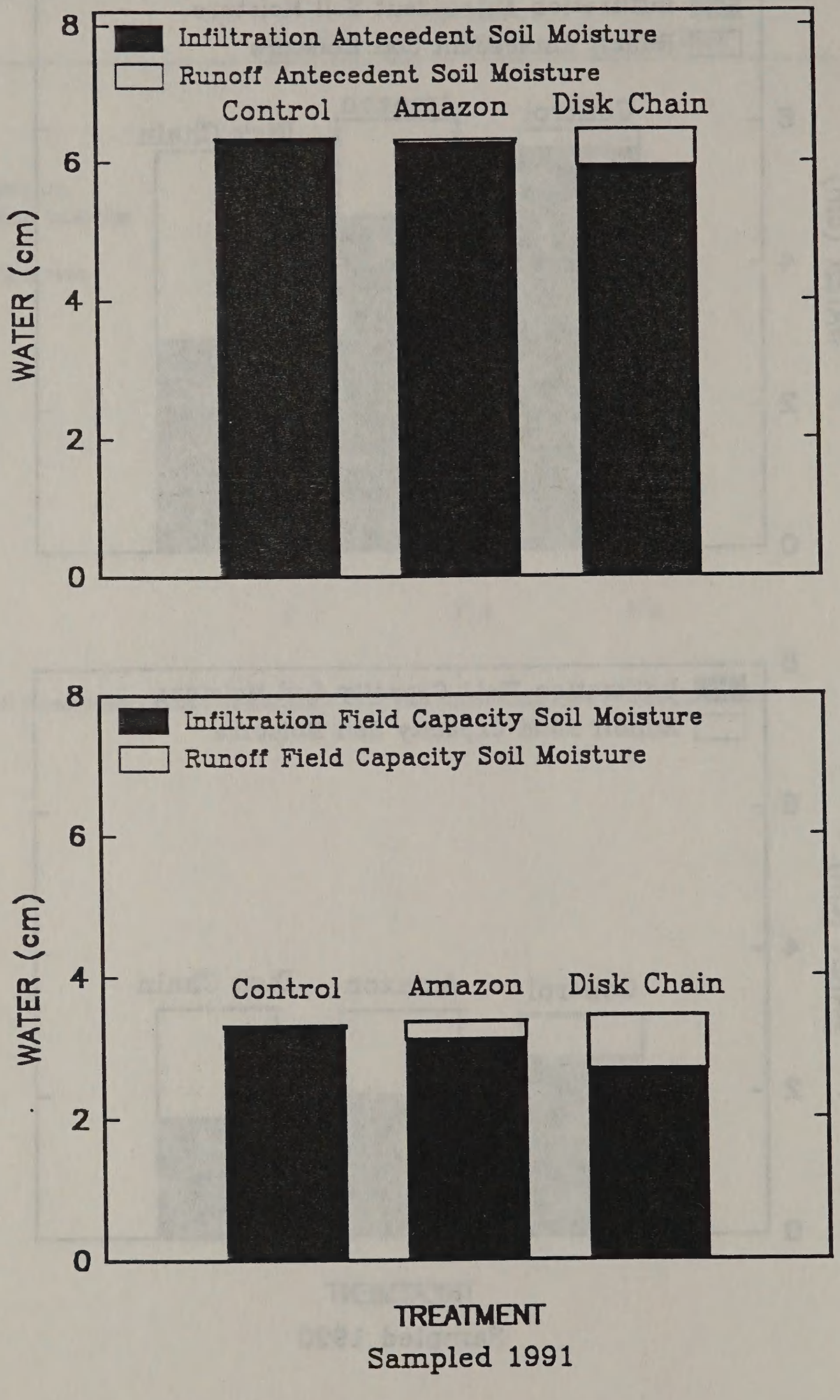


Figure 2.14 Continued

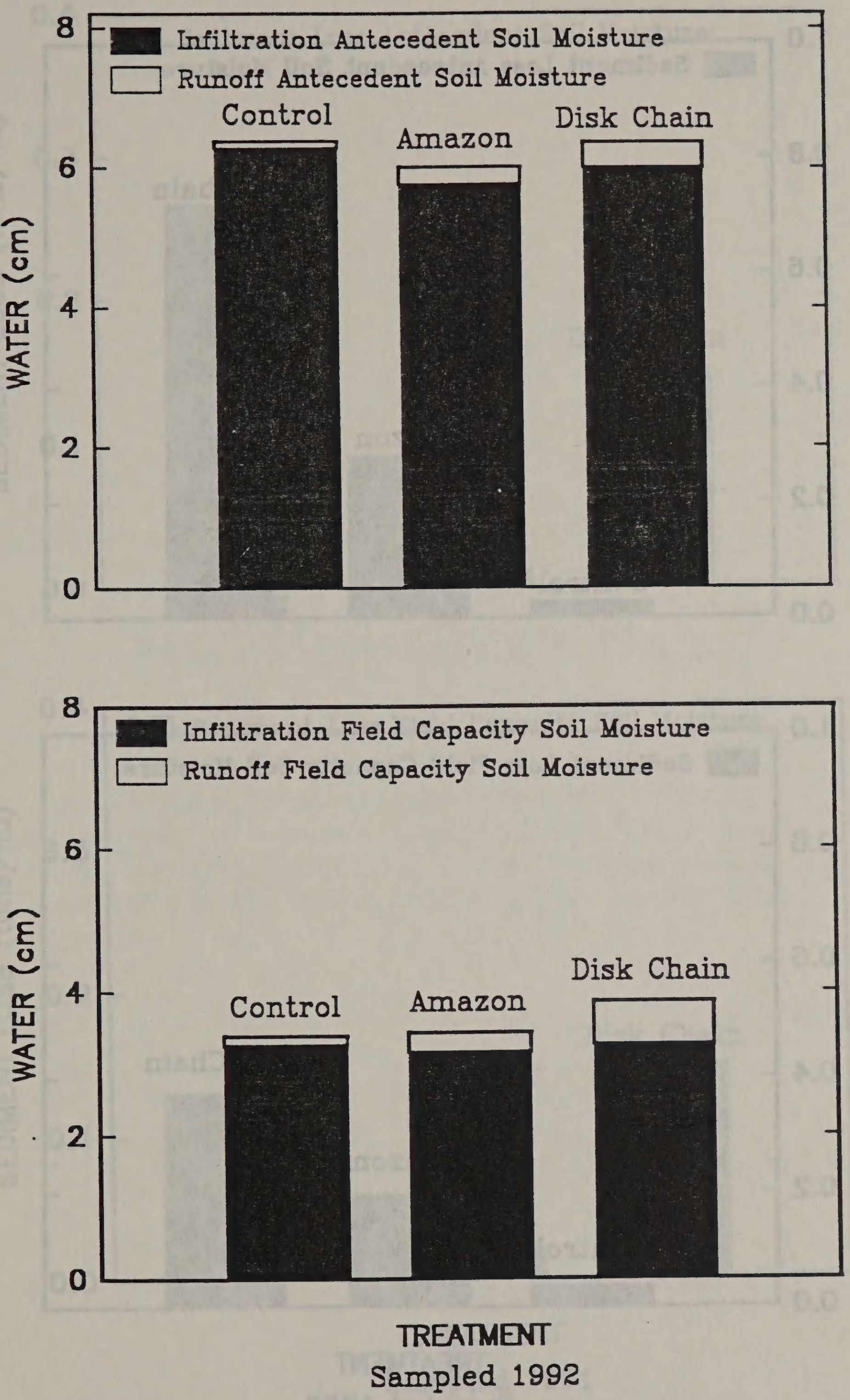


Figure 2.14 Continued

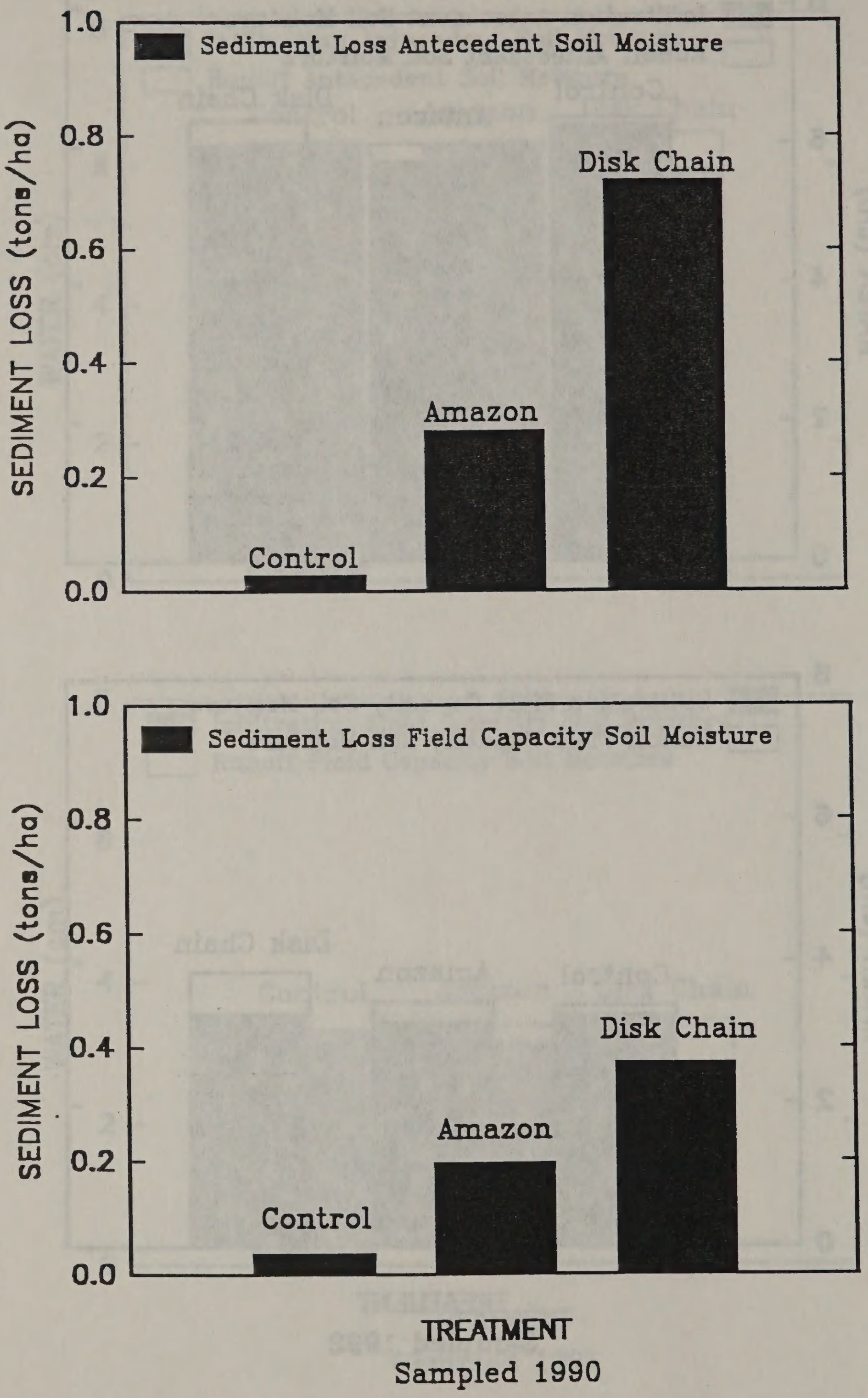


Figure 2.15 Post-treatment mean sediment loss for antecedent and field capacity soil moisture conditions. Sampled 1990-1992. Lockman Study Site, Mountain Home, Idaho.

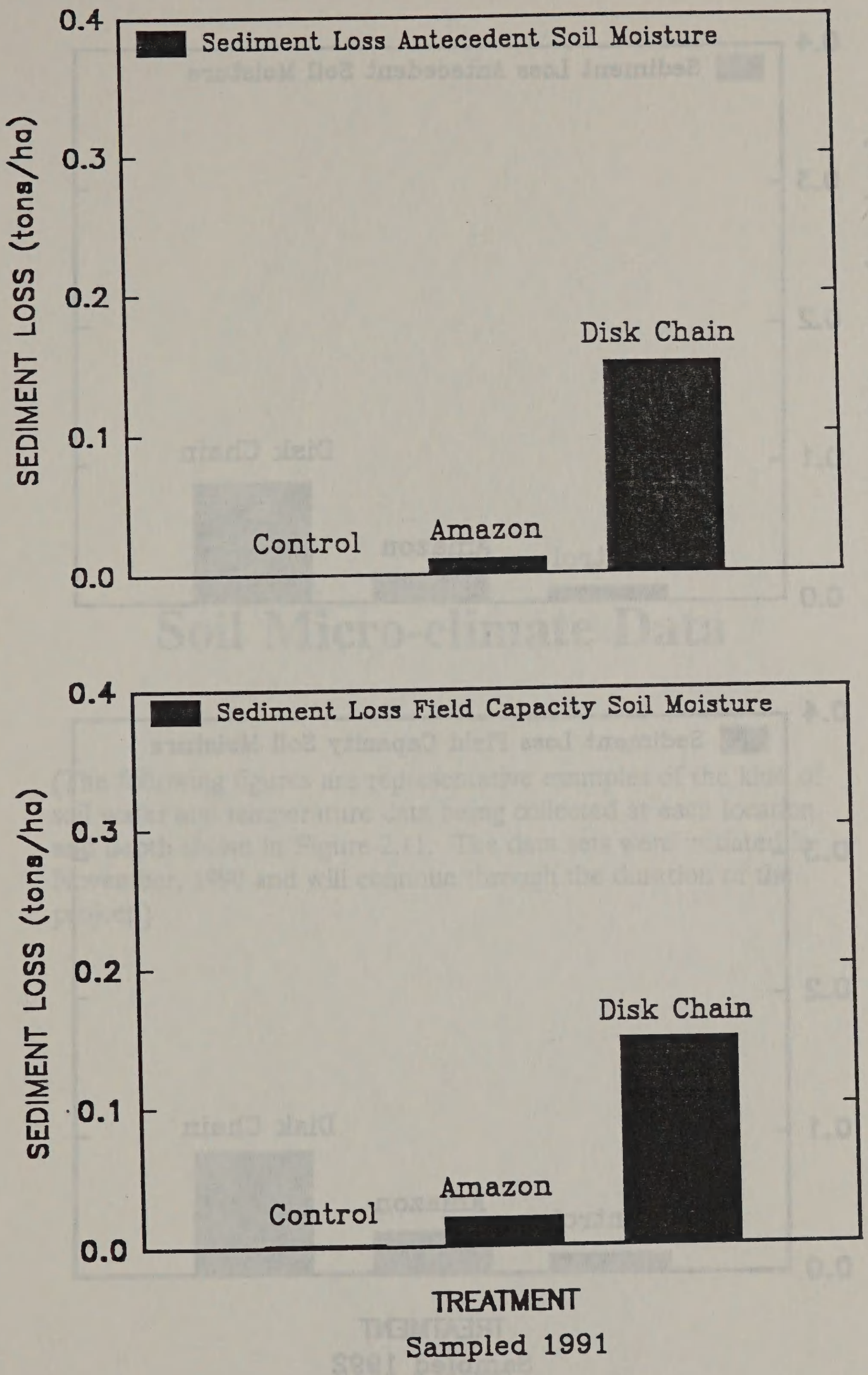


Figure 2.15 Continued

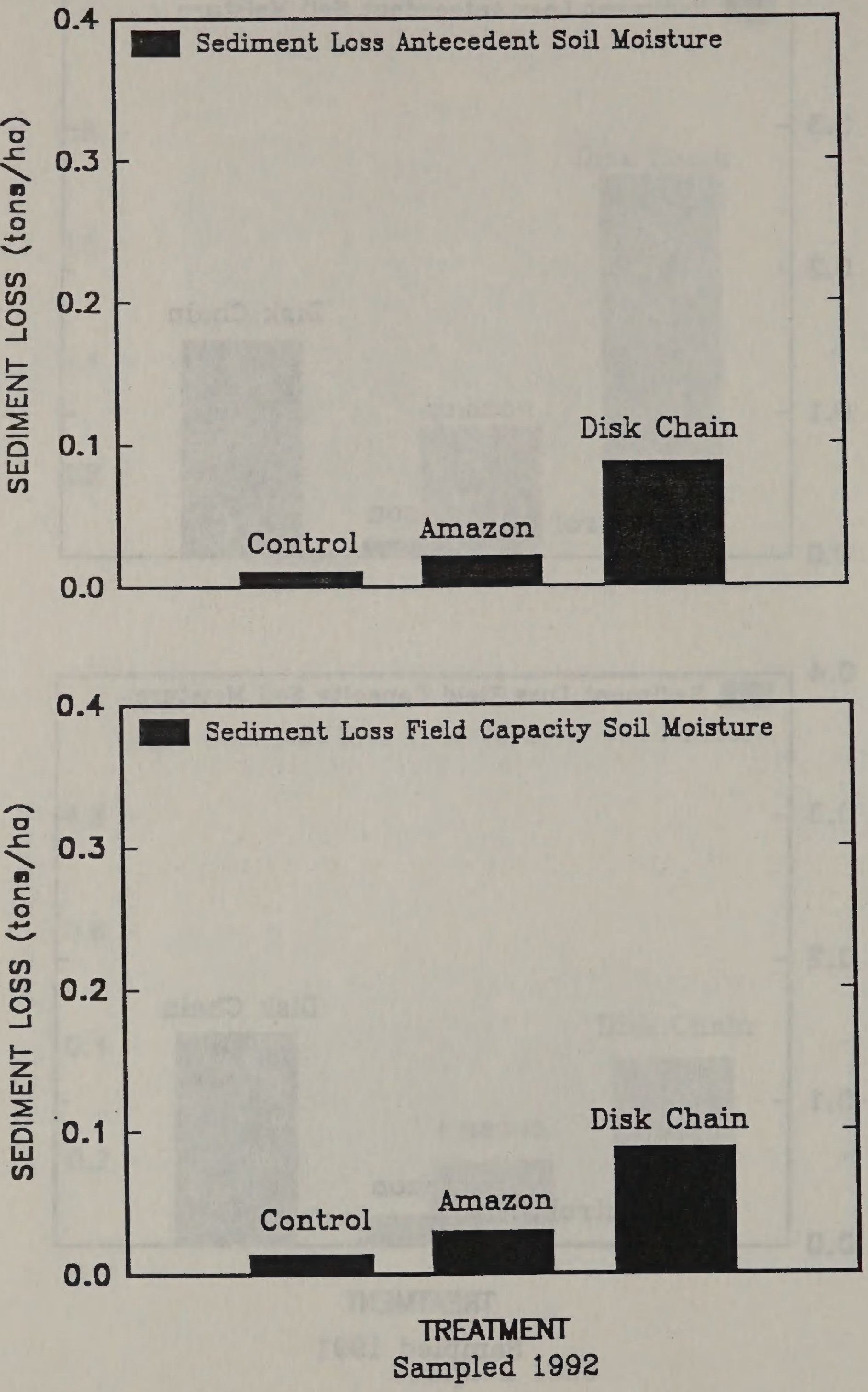


Figure 2.15 Continued

Soil Micro-climate Data

(The following figures are representative examples of the kind of soil water and temperature data being collected at each location and depth shown in Figure 2.11. The data sets were initiated in November, 1990 and will continue through the duration of the project.)

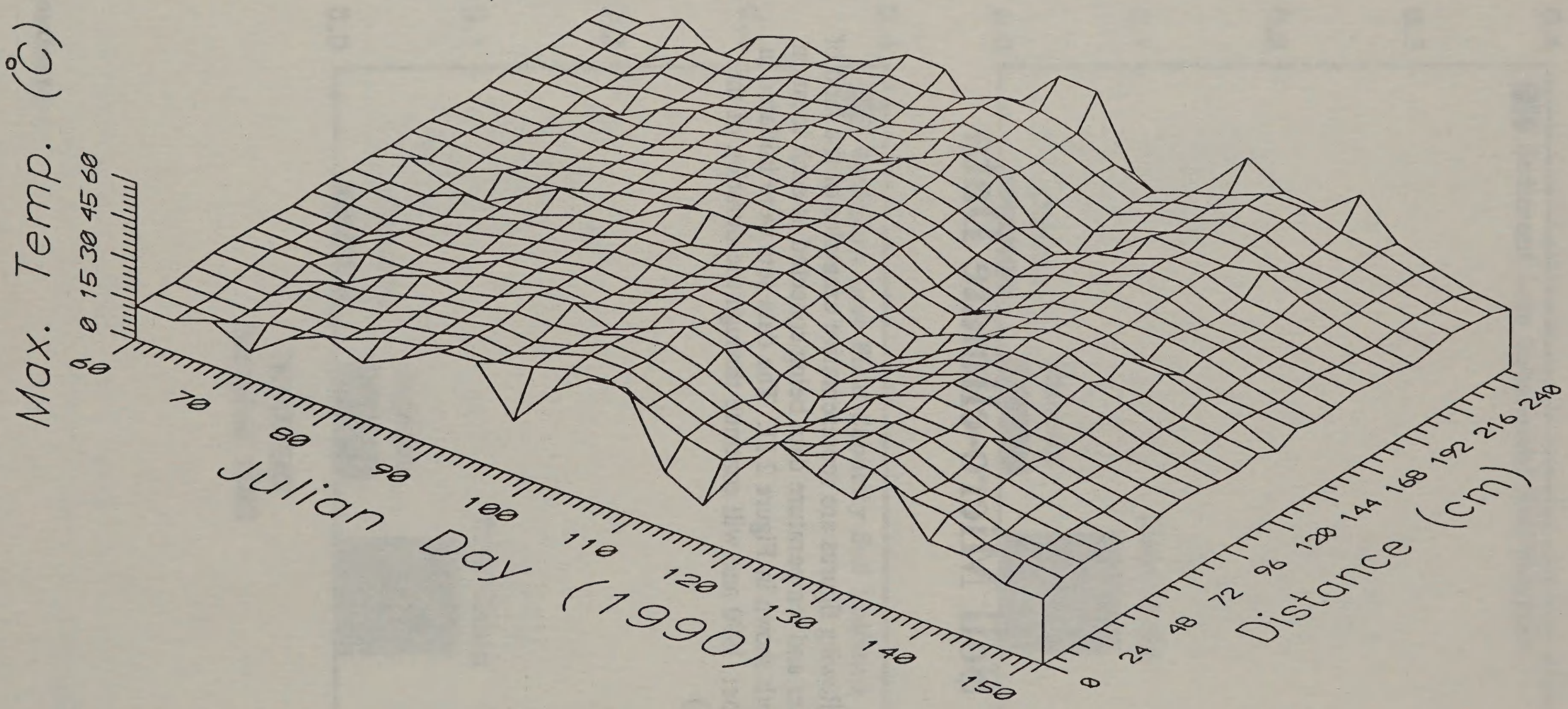


Figure 2.16 Maximum soil temperature at the 1-cm depth for each sample location along an East-West transect within the control treatment (Fig. 2.11) for Julian Days 60-151, 1990. Lockman Study Site, Mountain Home, Idaho.

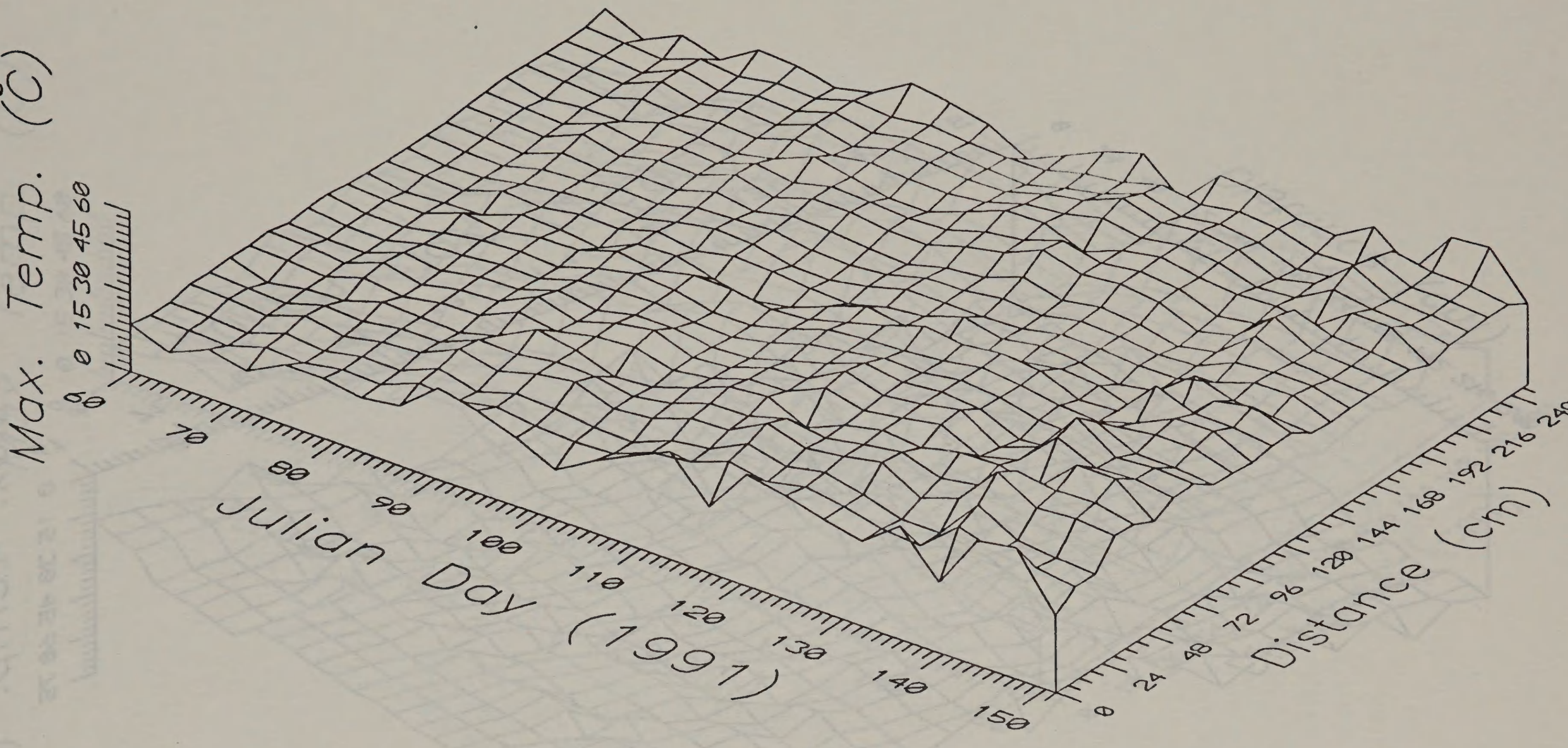


Figure 2.17 Maximum soil temperature at the 1-cm depth for each sample location along an East-West transect within the control treatment (Fig. 2.11) for Julian Days 60-151, 1991. Lockman Study Site, Mountain Home, Idaho.

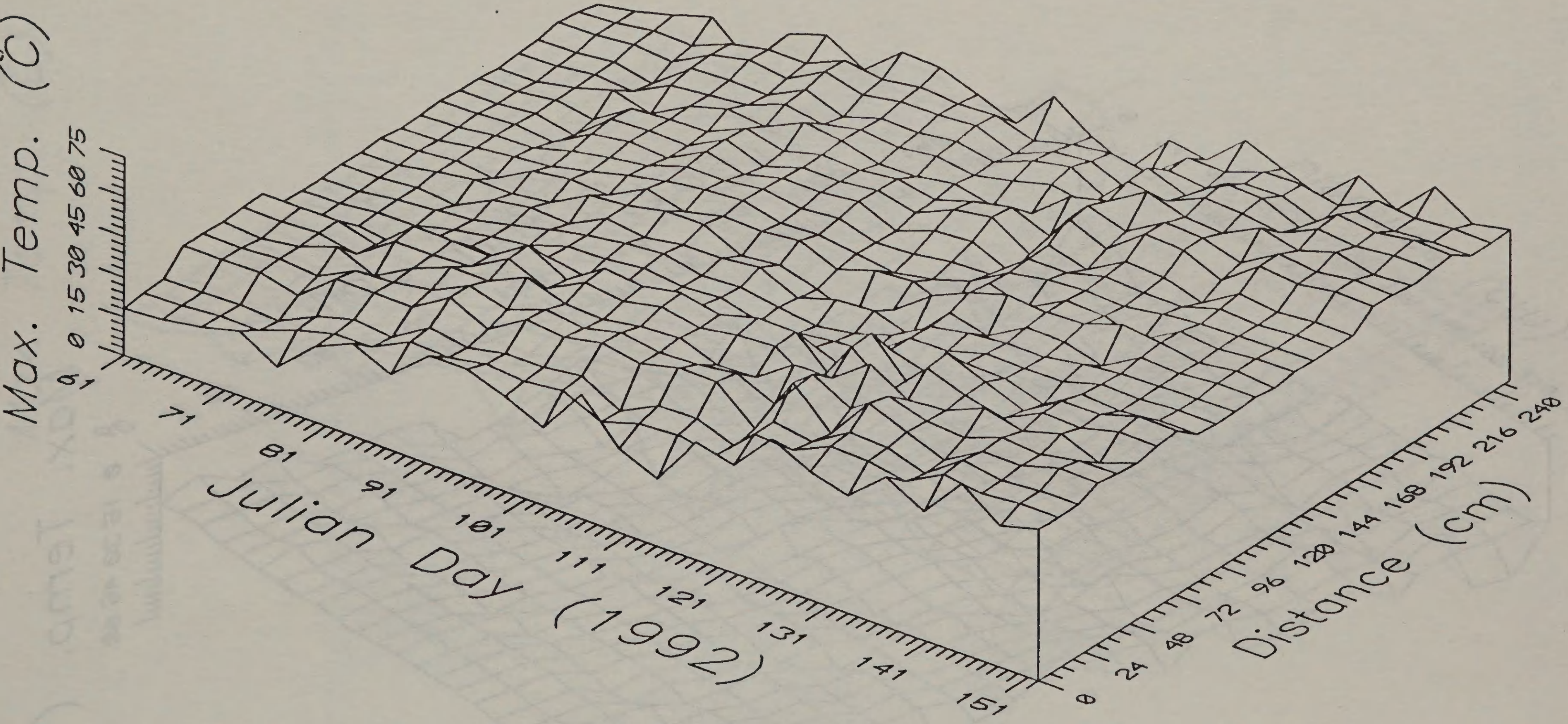


Figure 2.18 Maximum soil temperature at the 1-cm depth for each sample location along an East-West transect within the control treatment (Fig. 2.11) for Julian Days 61-152, 1992. Lockman Study Site, Mountain Home, Idaho.

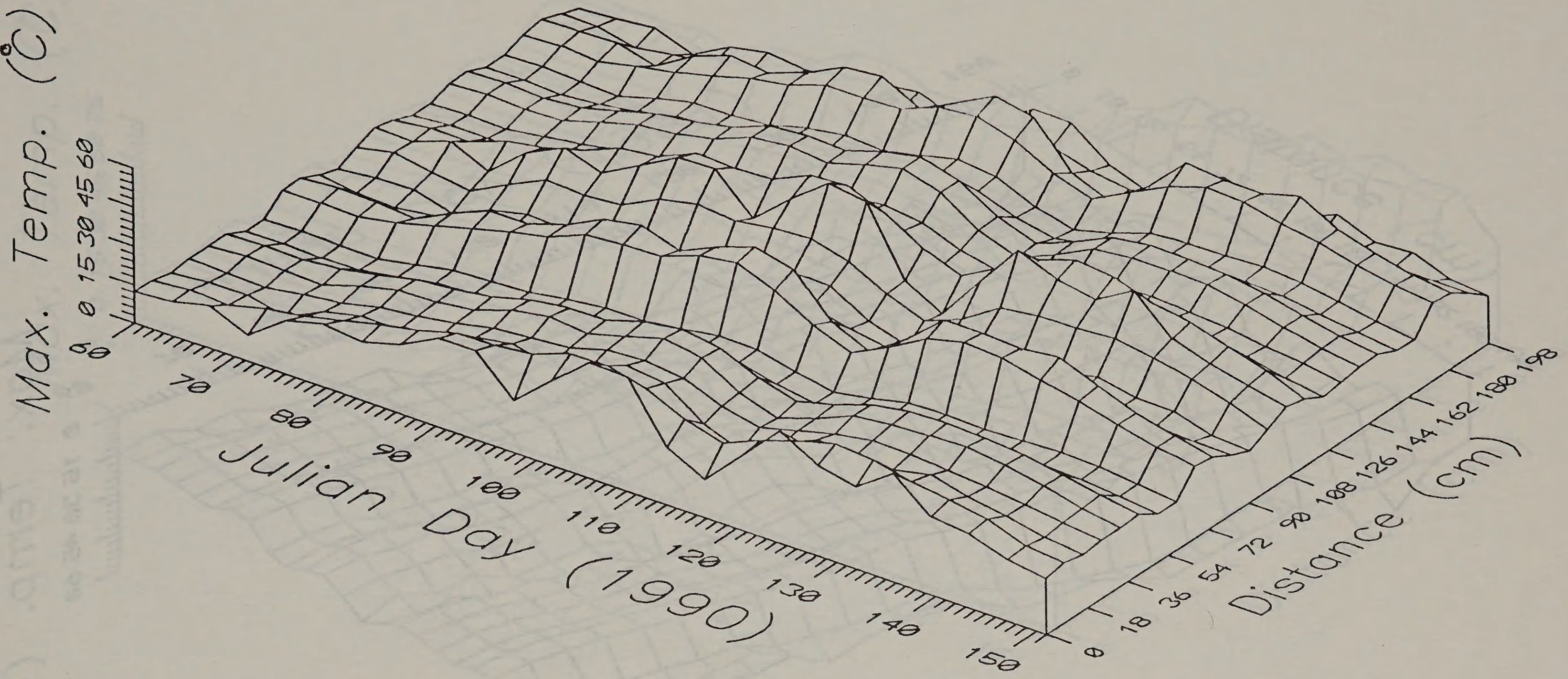


Figure 2.19 Maximum soil temperature at the 1-cm depth for each sample location along an East-West transect within the Amazon Drill treatment (Fig. 2.11) for Julian Days 60-151, 1990. Lockman Study Site, Mountain Home, Idaho.

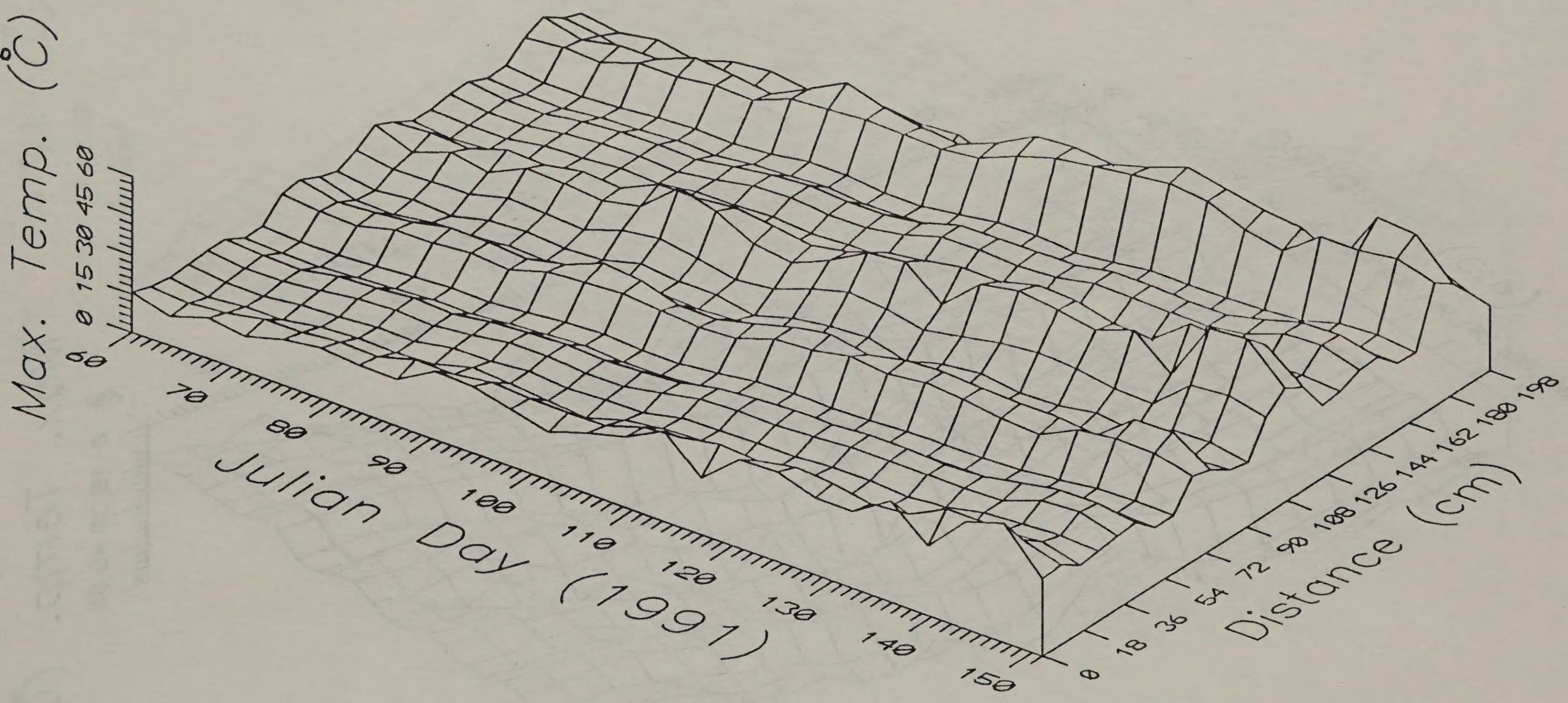


Figure 2.20 Maximum soil temperature at the 1-cm depth for each sample location along an East-West transect within the Amazon Drill treatment (Fig. 2.11) for Julian Days 60-151, 1991. Lockman Study Site, Mountain Home, Idaho.

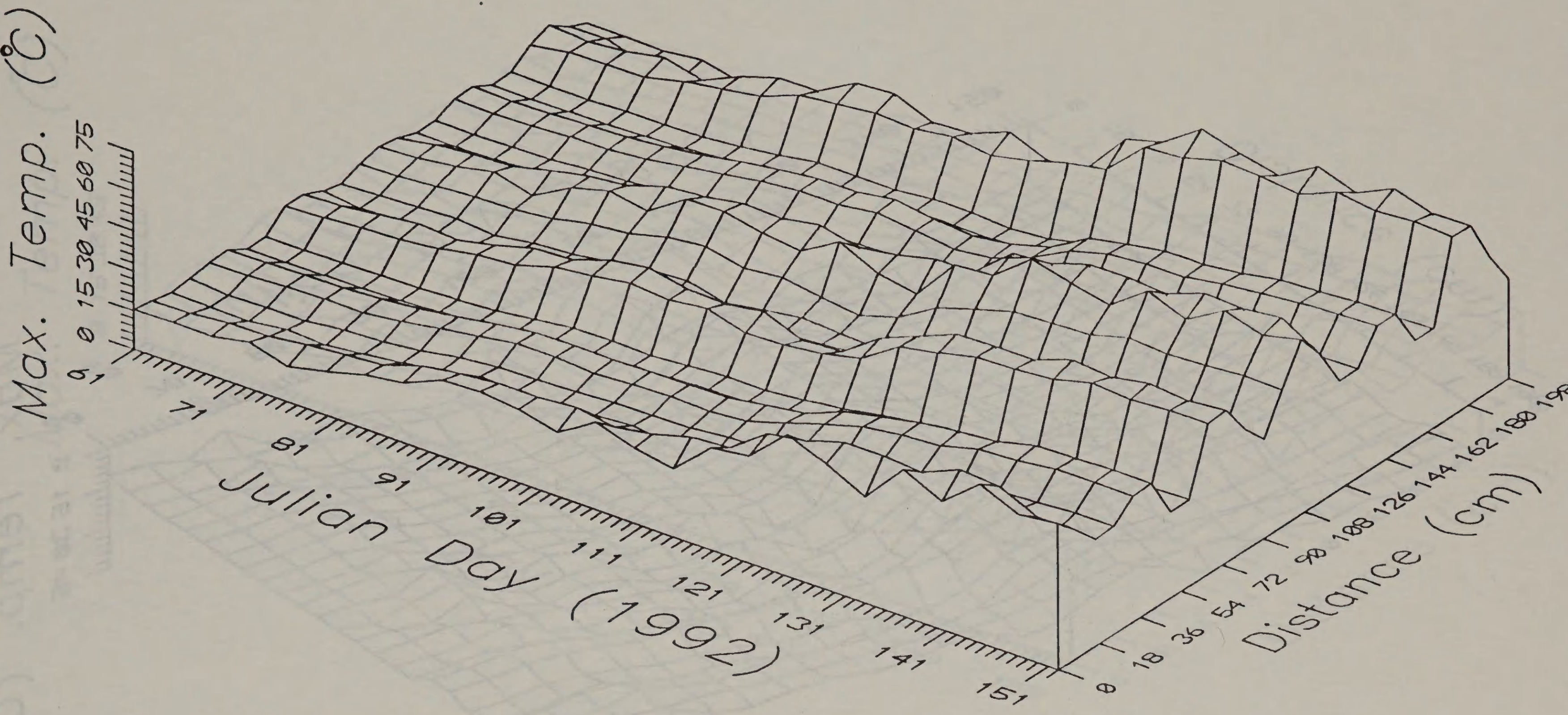


Figure 2.21 Maximum soil temperature at the 1-cm depth for each sample location along an East-West transect within the Amazon Drill treatment (Fig. 2.11) for Julian Days 61-152, 1992. Lockman Study Site, Mountain Home, Idaho.

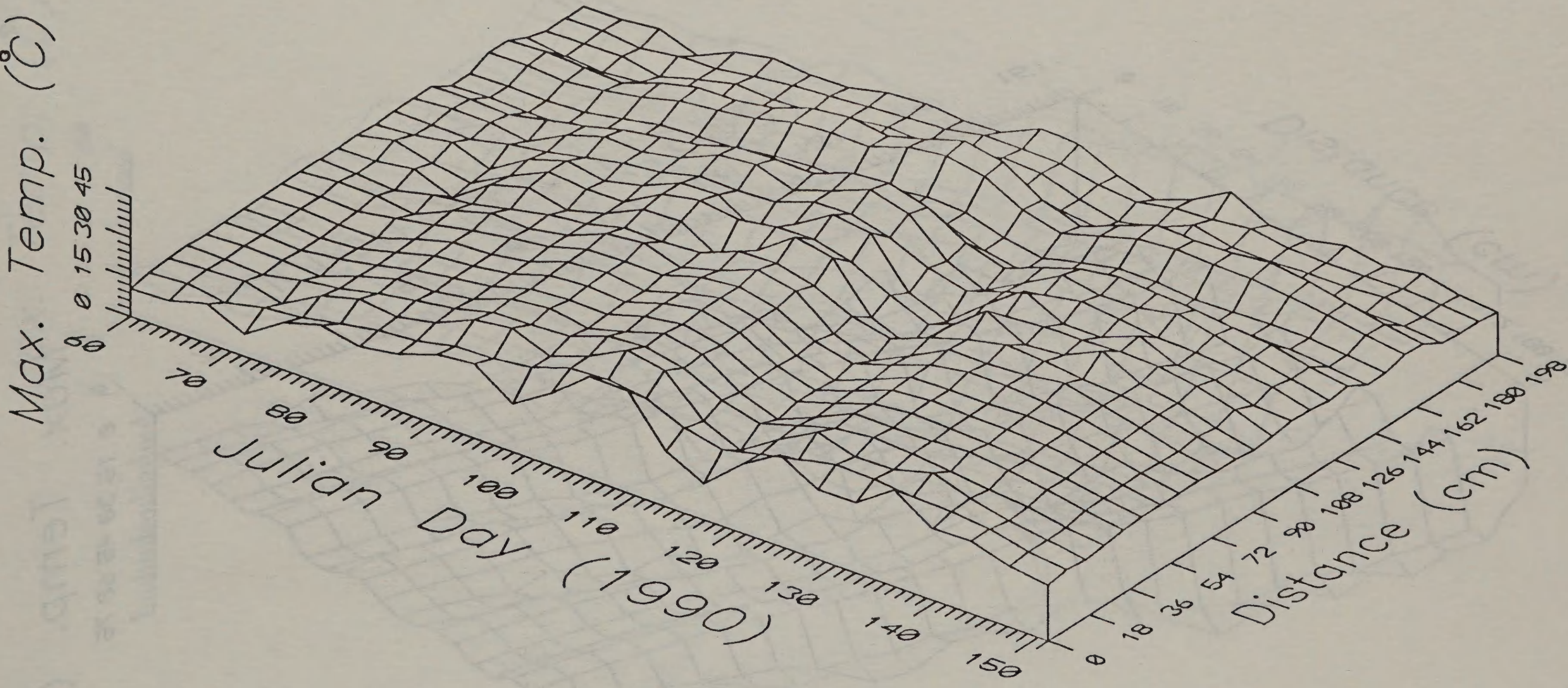


Figure 2.22 Maximum soil temperature at the 1-cm depth for each sample location along an East-West transect within the Disk Chain treatment (Fig. 2.11) for Julian Days 60-151, 1990. Lockman Study Site, Mountain Home, Idaho.

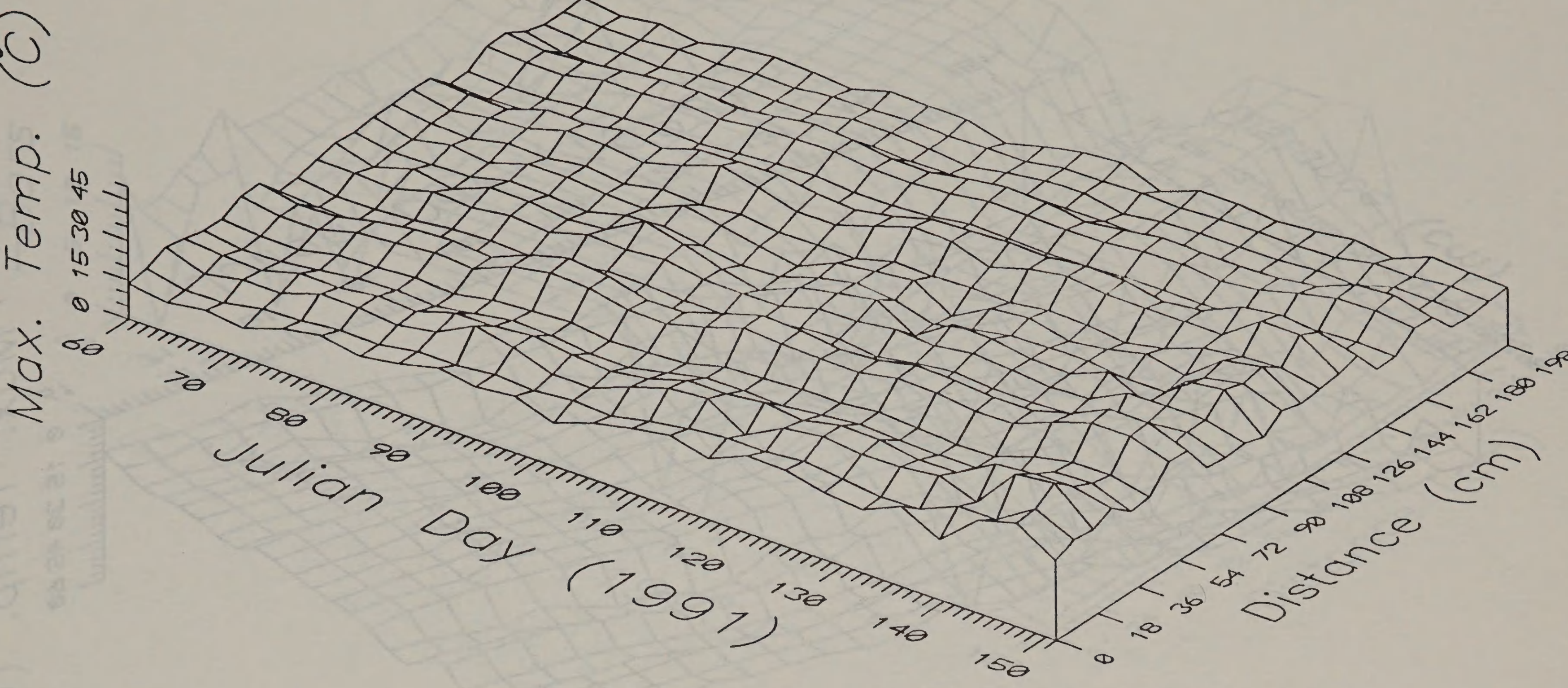


Figure 2.23 Maximum soil temperature at the 1-cm depth for each sample location along an East-West transect within the Disk Chain treatment (Fig. 2.11) for Julian Days 60-151, 1991. Lockman Study Site, Mountain Home, Idaho.

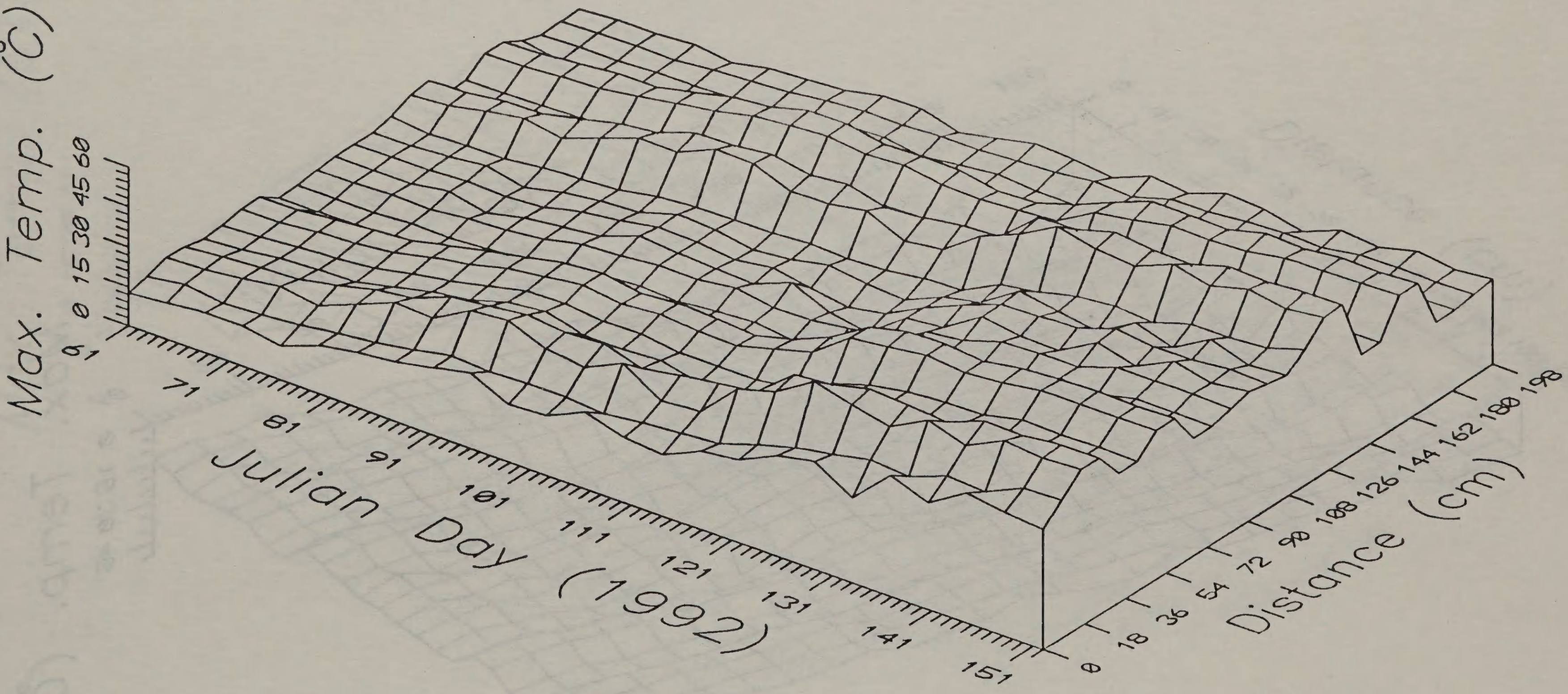


Figure 2.24 Maximum soil temperature at the 1-cm depth for each sample location along an East-West transect within the Disk Chain treatment (Fig. 2.11) for Julian Days 61-152, 1992. Lockman Study Site, Mountain Home, Idaho.

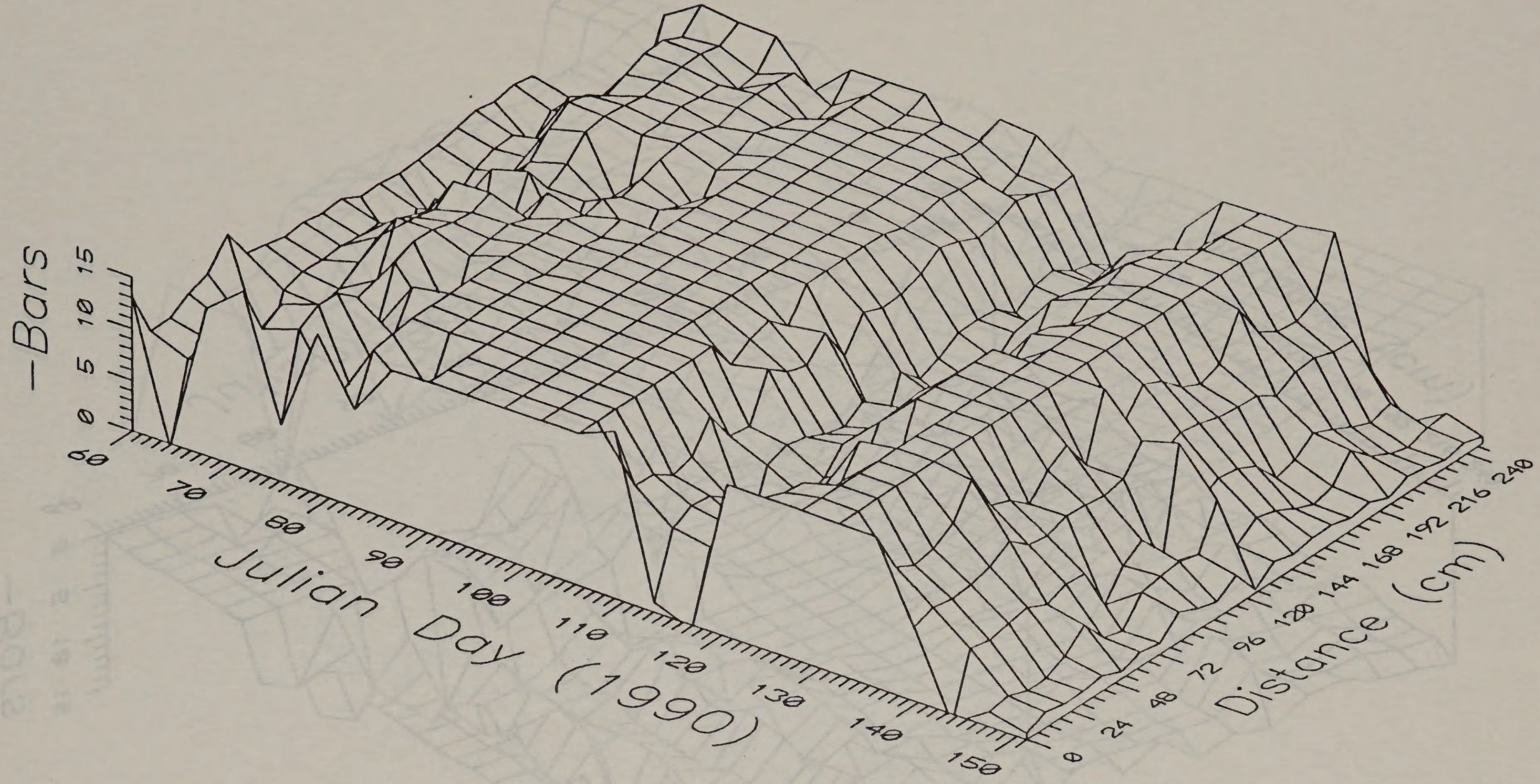


Figure 2.25 Water potential at the 1-cm depth for each sample location along an East-West transect within the Control treatment (Fig. 2.11) for Julian Days 60-151, 1990. Lockman Study Site, Mountain Home, Idaho.

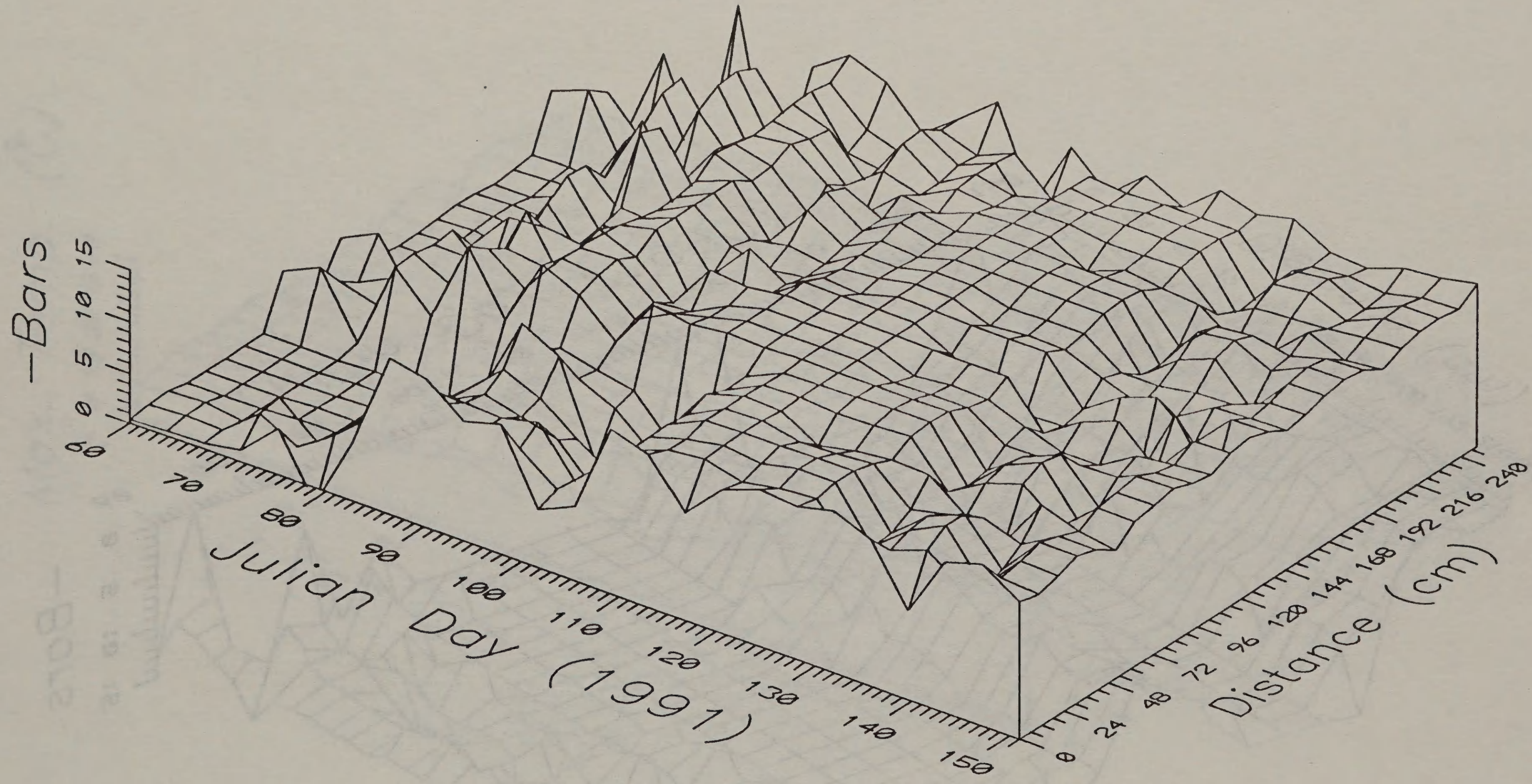


Figure 2.26 Water potential at the 1-cm depth for each sample location along an East-West transect within the Control treatment (Fig. 2.11) for Julian Days 60-151, 1991. Lockman Study Site, Mountain Home, Idaho.

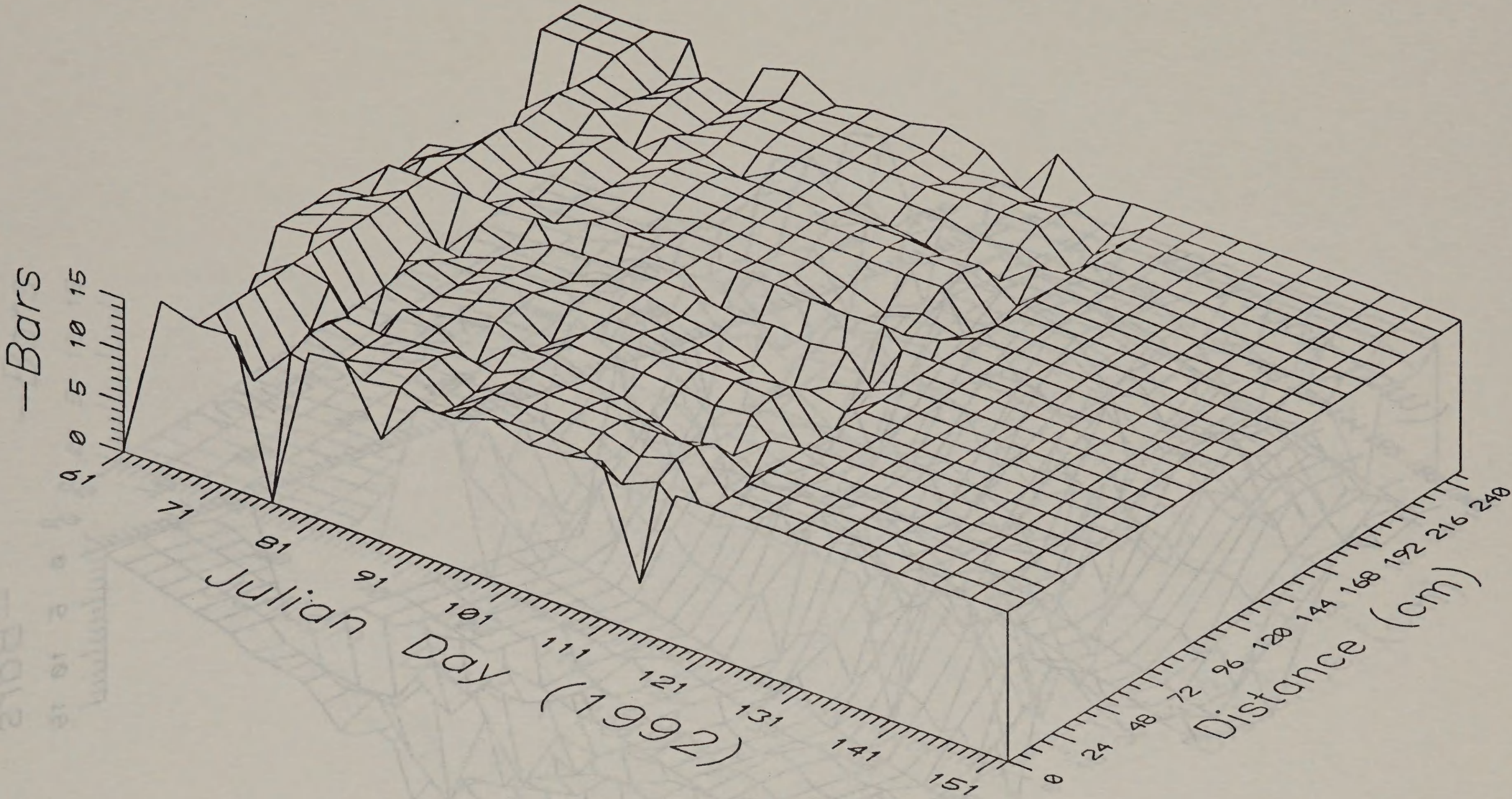


Figure 2.27 Water potential at the 1-cm depth for each sample location along an East-West transect within the Control treatment (Fig. 2.11) for Julian Days 61-152, 1992. Lockman Study Site, Mountain Home, Idaho.

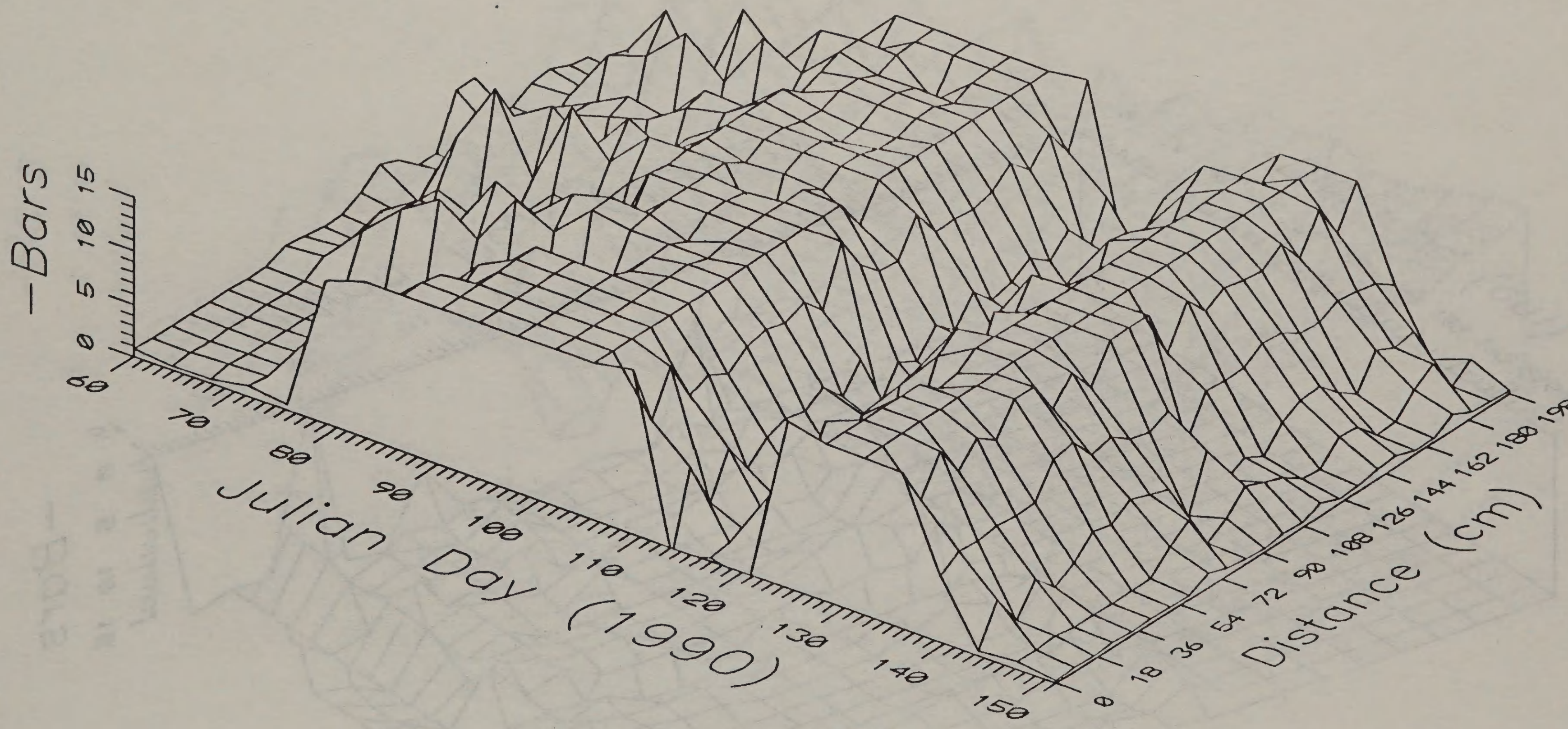


Figure 2.28 Water potential at the 1-cm depth for each sample location along an East-West transect within the Amazon Drill treatment (Fig. 2.11) for Julian Days 60-151, 1990. Lockman Study Site, Mountain Home, Idaho.

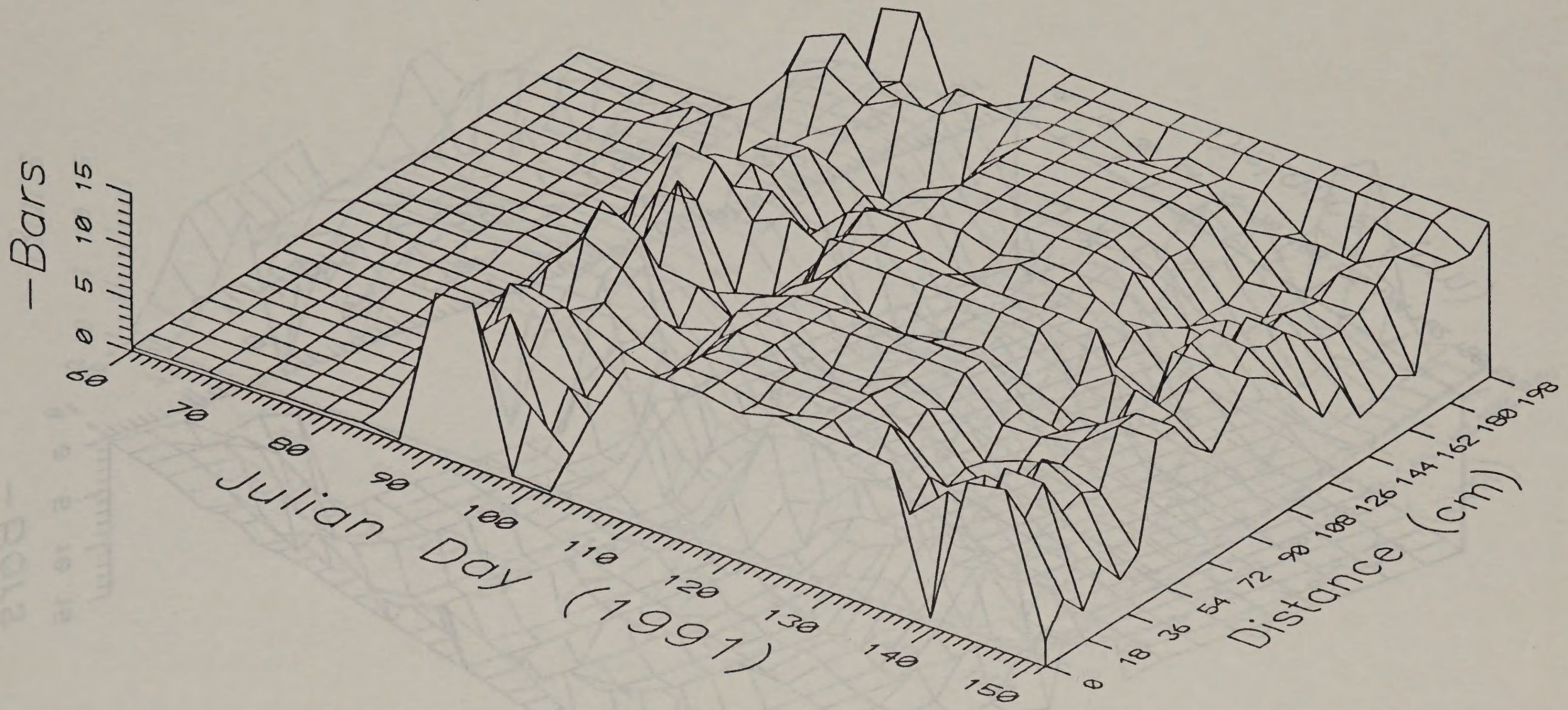


Figure 2.29 Water potential at the 1-cm depth for each sample location along an East-West transect within the Amazon Drill treatment (Fig. 2.11) for Julian Days 60-151, 1991. Lockman Study Site, Mountain Home, Idaho.

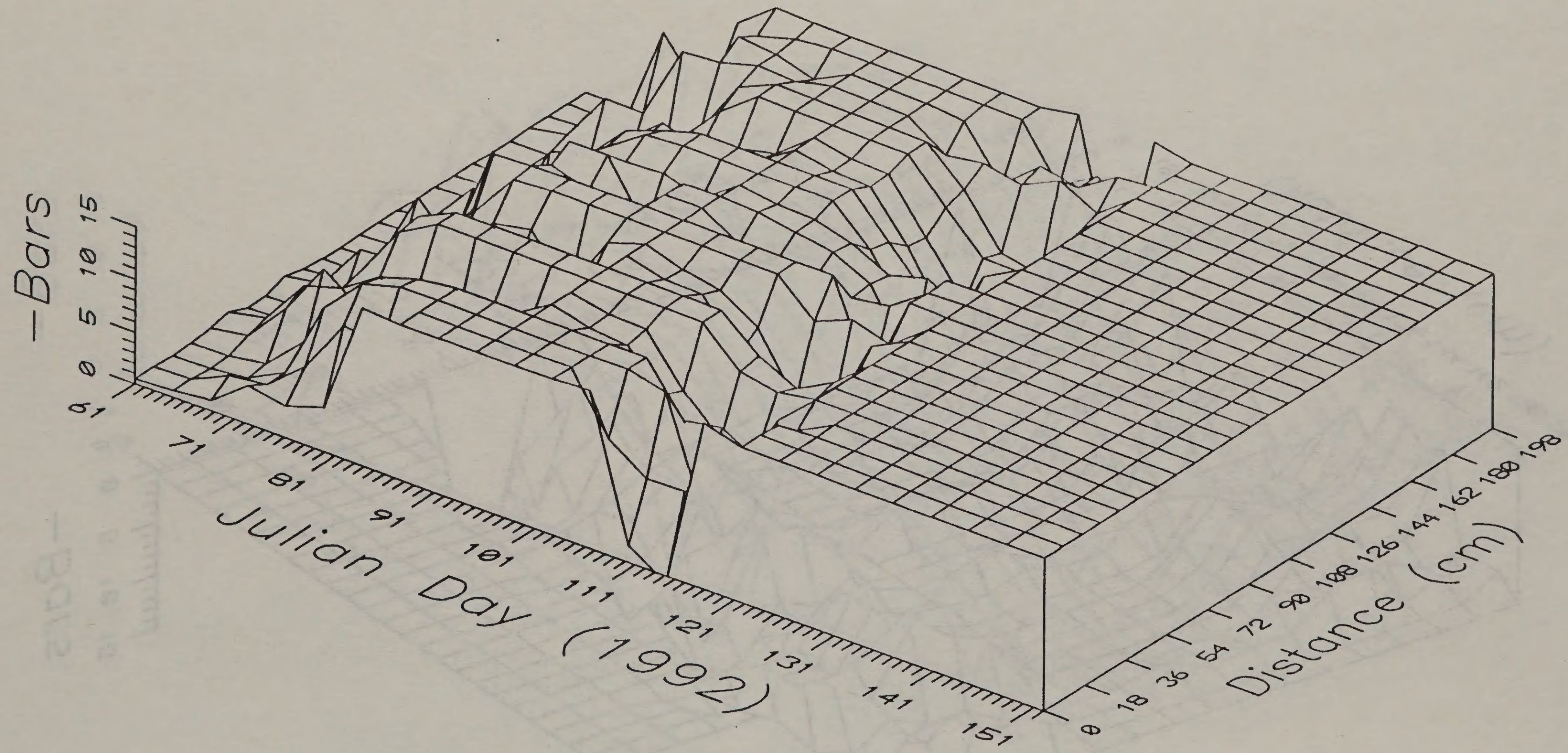


Figure 2.30 Water potential at the 1-cm depth for each sample location along an East-West transect within the Amazon Drill treatment (Fig. 2.11) for Julian Days 61-152, 1992. Lockman Study Site, Mountain Home, Idaho.

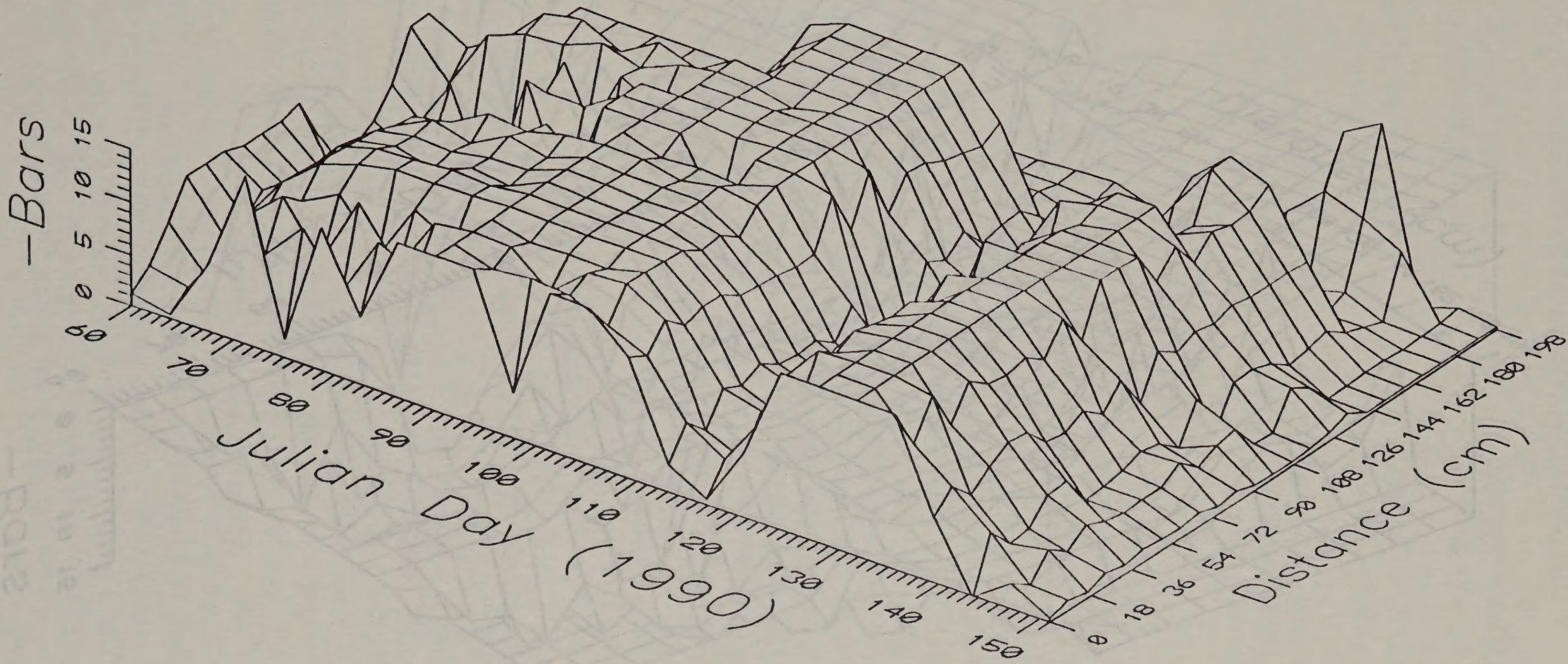


Figure 2.31 Water potential at the 1-cm depth for each sample location along an East-West transect within the Disk Chain treatment (Fig. 2.11) for Julian Days 60-151, 1990. Lockman Study Site, Mountain Home, Idaho.

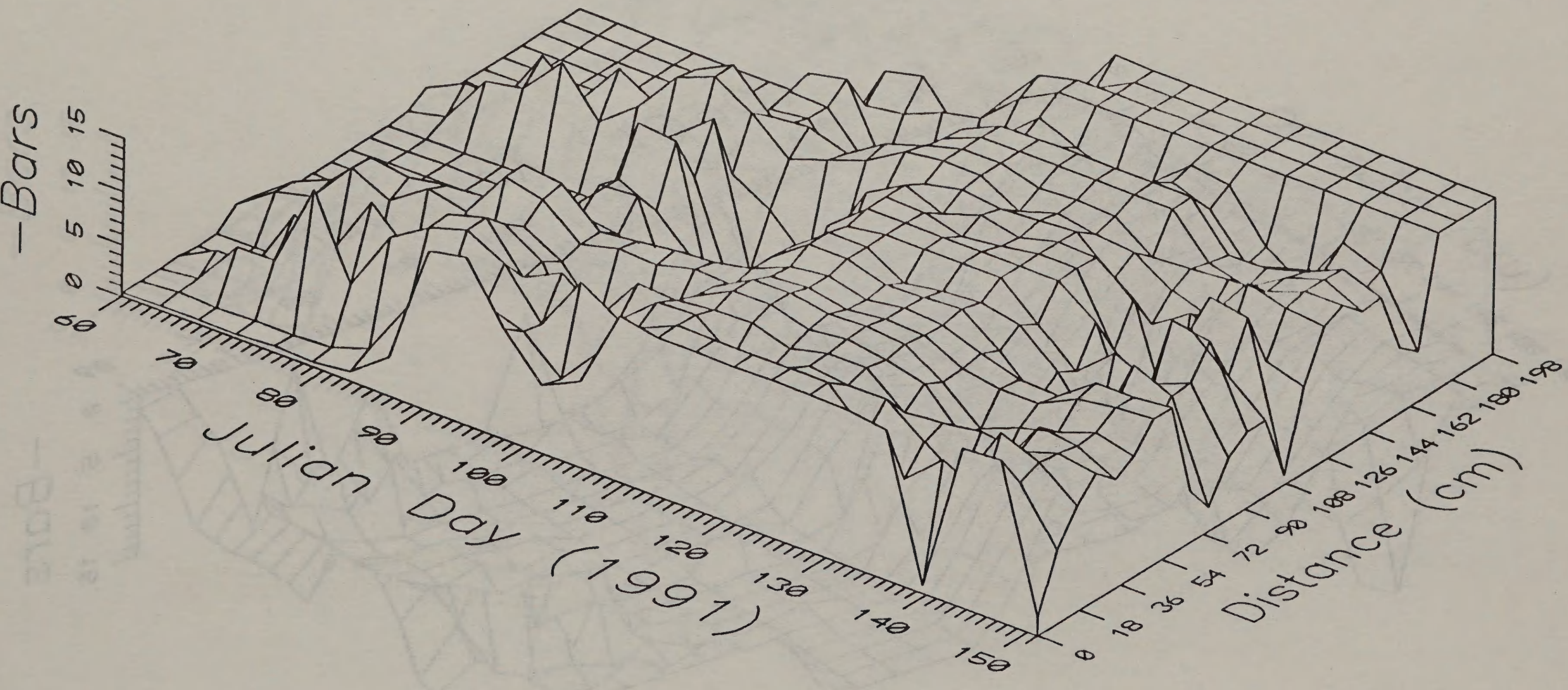


Figure 2.32 Water potential at the 1-cm depth for each sample location along an East-West transect within the Disk Chain treatment (Fig. 2.11) for Julian Days 60-151, 1991. Lockman Study Site, Mountain Home, Idaho.

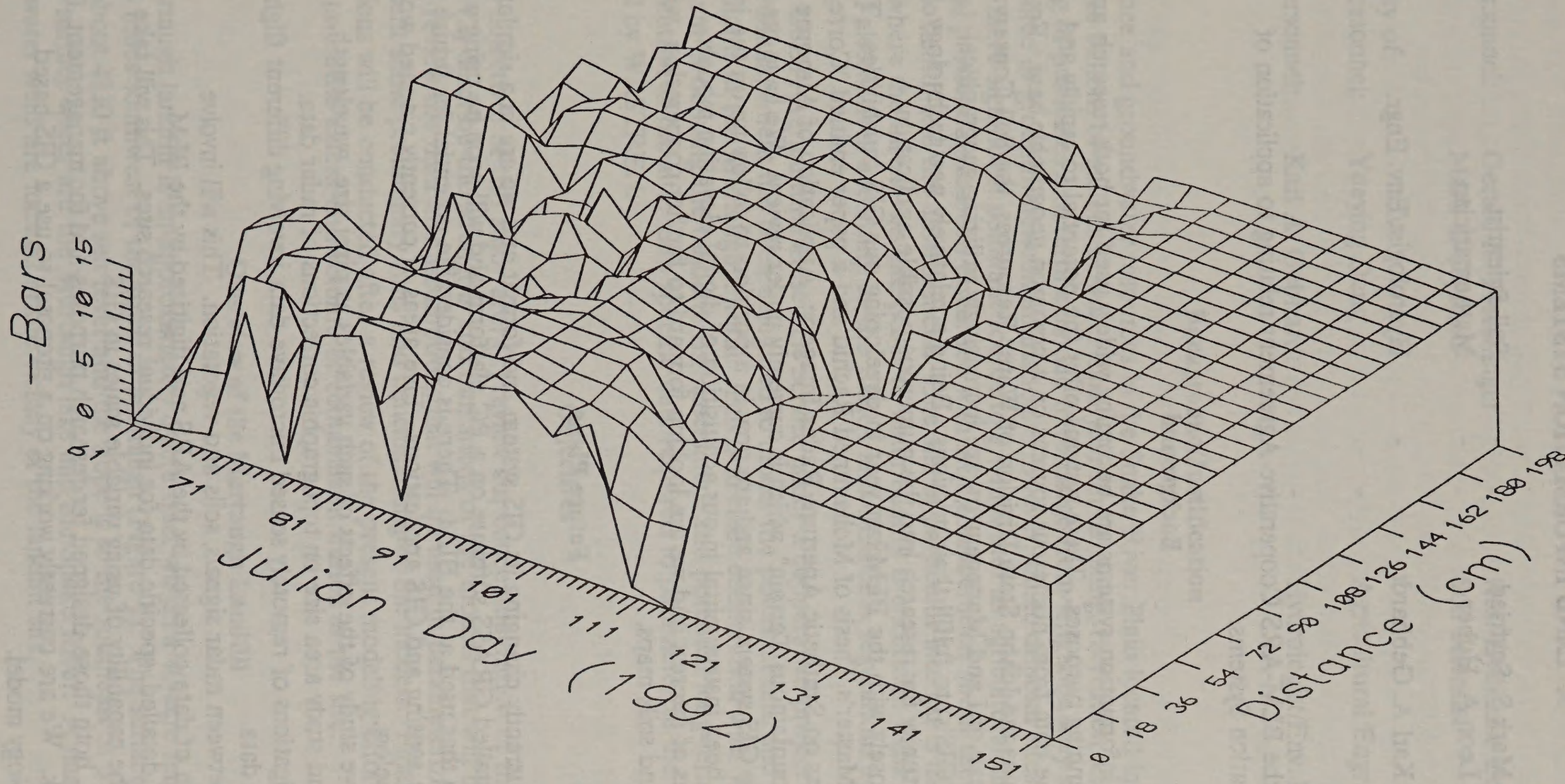


Figure 2.33 Water potential at the 1-cm depth for each sample location along an East-West transect within the Disk Chain treatment (Fig. 2.11) for Julian Days 61-152, 1992. Lockman Study Site, Mountain Home, Idaho.

5. LAND INFORMATION SYSTEMS

ARS Personnel:	Mark S. Seyfried	-	Soil Scientist
	Leon A. Huber	-	Mathematician
BLM Personnel:	Karl A. Gebhardt	-	Hydrologist/Env. Engr.

Progress Report for the BLM-ARS Cooperative Agreement relating to application of Geographical Information Systems.

Background

Geographical information systems are becoming widely used for both research and land management/planning purposes. These systems offer the potential to rapidly and quantitatively combine data from numerous sources on a common geographic base. For this reason, agencies such as the Idaho State Division of Water Resources, the Soil Conservation Service, and the Bureau of Land Management, are increasingly utilizing geographical information systems (GIS's) to fulfill their missions. Being a relatively new technology, there is considerable opportunity for research into the numerous possible applications.

We worked closely with the BLM last year in developing our GIS capabilities. That work resulted in the Master's Thesis of Mohammed Rachid and a paper entitled "Correction of Topographic Effects on Synthetic Aperture Radar Imagery: Application of Airborne Data to Semiarid, Mountainous Terrain", which is currently under review. We have made several changes in our GIS system since and are now in a position to follow up on the initial work. The BLM has been instrumental in our acquisition of digital elevation models (DEM's) for our areas of interest and we are looking forward to further cooperation with digitized vegetation and soils maps.

Future Plans

The BLM is currently changing its GIS system and format and we are in a similar process. We have installed GRASS software on a PC platform and will soon be using a workstation similar to that used at the BLM. There is considerable potential for future work in this area of remote sensing and GIS applications. Five areas of currently planned work using GIS are listed below.

1. More exhaustive study of the effects of such variables as pixel size, wavelength, polarization and study area size on topographic corrections of radar data.
2. Further investigations of remotely sensed microwave data involving different flights and calibrated data.
3. Correlations between radar signals, soils and vegetation. This will involve implementation of data collected by the ARS and digitized by the BLM.
4. Digitization of detailed, specific data for individual research sites. This will take advantage of the capability of using variable scales in GIS.
5. Use of models, both those designed for research purposes and for management, in a GIS framework. We are currently working on a proposal to use a GIS-based research hydrology model.

6. MODELING HAZARDOUS WASTE MIGRATION

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Background/Justification

Surface and groundwater resources in the Snake River Plain located in southern Idaho contribute billions of gallons of water each year for drinking, recreation and irrigation. Leaching of pesticides and fertilizers due to recharge from irrigation may serve as a non-point source of groundwater contamination. However, waste disposal sites are a known and perhaps more significant pollutant source to groundwater as agricultural chemicals and biological products have been discarded with little consideration about their potential impact on public health and the environment. One site of particular interest is the Murtaugh landfill where the threat this site poses to water quality is uncertain. Risk assessment and remedial alternatives according to the RCRA and CERCLA regulations are imperative at this site.

The USDA Agricultural Research Service under a cooperative project with the Bureau of Land Management has been delegated to model the potential fate and transport of contaminants at the Murtaugh landfill. This is in close cooperation with WASTREN to assist them in defining the baseline risk assessment and potential long-term extent of contamination at the site. Site specific data required to parameterize the models will be supplied by WASTREN.

Objectives

The objectives of this study are: (1) review our conceptualization of the Murtaugh landfill; (2) describe the strengths and limitations of the models that will be applied to the site; (3) review the data and assumptions that will be used to parameterize the models; and (4) present some preliminary runs and benchmarking of the models. Final model simulations will be conducted after a review of the present modeling efforts and receipt of final data on the extent and volume of contaminant buried at the site.

Overview of the Murtaugh Landfill

Murtaugh landfill is an approximately 6-acre tract within a 40-acre fenced area located about 3 miles southwest of the town of Murtaugh (Figure 1). The surface elevation of the site is about 4330 ft above sea level and the slope is to the southeast at 3 percent. The nearest surface water are the Murtaugh lake and the Snake River. A number of groundwater wells are located in the vicinity of the landfill site.

Waste disposal sites are regulated by a three-dimensional attenuation zone, bounded at the top by the ground surface, below by the base of the uppermost aquifer, and on each side by a compliance distance. The situation at the Murtaugh landfill is complicated because the large quantity of highly-concentrated liquid pesticides and the heterogeneous layering of the underlying geological formation could cause the contaminant to exit the regulated boundaries from different transport paths. Also, the low water solubility of disulfoton (but much greater than drinking water standard) may cause a non-aqueous phase liquid (NAPL) to travel along with the water-solute phase, depending upon the leaking rate of disulfoton and the soil water content. This modeling plan describes the general background of the Murtaugh landfill and the approaches that will be taken to simulate the contaminant transport.

***Trench Excavation*:** Prior to trench excavation, geophysical surveys using electromagnetic, surface resistivity, and ground penetrating radar methods were conducted (IT, 1990) to determine the locations and geometries of the disposal trenches. Nine separate disposal trenches, designated as D-1 to D-9, were identified as shown in Figure 2. To sample the buried materials, ten exploration trenches, designated as ET-1 to ET-10, were excavated parallel to or across the disposal trenches. Each disposal trench was exposed by at least one exploration trench during the excavation. A cross-sectional representation of the nine disposal trenches (A-A') is given in Figure 3 where a continuous caliche layer is assumed beneath the disposal trenches (because discontinuity of caliche was unable to be determined).

During excavation, large numbers of 55-gallon drums and 5-gallon canisters were found tightly packed in the disposal trenches. Many of these metallic containers were corroded to rupture and the liquid wastes had leaked into the bottom of the trenches. A few buried containers were retrieved from each disposal trench for examination. The 55-gallon drums were found either empty or containing minor quantity of liquids (generally less than 5 gallons), while the 5-gallon canisters were observed partially or completely full of liquid wastes. Liquid samples from retrieved containers and soil samples from trench bottom were taken for analysis. Results showed that the liquid was mainly disulfoton with concentrations ranging from 12,000 to 790,000 ppm. Soil from trench bottom was found to be contaminated with disulfoton concentration up to 190 ppm. Despite the trench excavations, the depth and horizontal extent of the soil contamination could not be determined and the volumes and concentrations of the liquid wastes in most of the containers remain unknown. Further information on drum conditions and liquid waste at the site will be provided by WASTREN after a more comprehensive field investigation.

***Pysicochemical Properties of Disulfoton*:** Disulfoton is an acutely toxic organophosphorus pesticide with a toxicity of 5.6 mg/kg (Ware, 1986). Within the Murtaugh landfill site vadose zone at alkaline condition (pH=7.8), disulfoton will degrade mainly by oxidation reaction. Even though disulfoton has a short half life of 19 days (McLean et al., 1988), its oxidation metabolites are every bit as toxic as disulfoton itself and more persistent in the soil environment. At 20 °C, disulfoton has a very low vapor pressure of 1.8×10^{-4} mm Hg or an equivalent volatility of 2.7 mg/m^3, so that vapor transport is insignificant. Henry's Law constant for disulfoton is 3.99×10^{-6} atm-m^3/mole and the specific weight is 1.144 g/cm^3. The octanol-water partition coefficient is equal to 4.02, which is used to calculate the distribution coefficients for different soils at the site.

Modeling Contaminant Transport

As revealed by the field investigations, two possible transport paths exist for the leaking pesticide to travel outside the regulated landfill boundaries. Although the Murtaugh landfill is located in the semi-arid area, an occasional heavy storm or intensive snowmelt may produce surface runoff or deep percolation. Water percolating through the vegetative root-zone layer may serve as an influential driving force for the leaking chemical to travel downward through the unsaturated soil to groundwater or flow laterally offsite above the low permeable caliche and dense basalt layers. Because of the complexity of the landfill conditions, contaminant properties, and the restrictions of the existing simulation models, a combination of three models will be used to evaluate the fate and migration of chemical at the site.

***Strengths and Limitations of simulation models*:** Since disulfoton has a low water solubility of 25 mg/L, the chemical will not be diluted immediately by small amount of water. A NAPL (highly concentrated disulfoton in organic solvent) might travel separate from the water-solute phase depending upon the leaking rate of disulfoton and soil water content. A variably-saturated, non-aqueous phase liquid transport model will be used to simulate the NAPL flow. SWANFLOW (Faust and Rumbauch, 1989) is a three-dimensional, finite-difference code for simulating the flow of water and an immiscible non-aqueous phase under saturated and unsaturated conditions. Two major shortcomings for applying this code to the Murtaugh site are: (1) no mass transfer between phases is considered, meaning the NAPL does not dissolve in water; and (2) data relating to capillary pressure and relative permeabilities on a site-specific basis are lacking. If the leaking rate of disulfoton is high and soil water content is low, the first limitation becomes negligible because most of leaking disulfoton will be in the non-aqueous phase. But this requires accurate knowledge of drum conditions and amount of disulfoton within the drums.

SWANFLOW requires the input data of capillary pressure versus saturations and relative permeabilities of water and NAPL in a soil-water-NAPL system, as well as capillary pressure versus saturations and relative permeabilities of air and NAPL in a soil-air-NAPL system. These data could be derived from the water retention curve of each soil type using the scaling technique (Parker et al., 1987; and Lenhard and Parker, 1987). However, water retention curve for the consolidated materials at the site, such as caliche and dense basalt, are not available. Using data from literature for other soil types to substitute will reduce the reliability of the simulation results. Therefore, the NAPL flow will be simulated within the loamy soil in which the described input data were obtained from laboratory analysis. For the scenarios with caliche layer, a clay which is assumed to have close hydraulic properties to caliche will be used to substitute the caliche layer, so that the downward movement of NAPL through a relatively impermeable layer could be simulated. The NAPL flow through the bottom of loamy soil will enter the fractured basalt.

Because the SWANFLOW model considers that no NAPL is dissolved in water, the VAM2D, also named SOILSIM model (Huyakorn et al., 1989) will be used to investigate the transport of dissolved disulfoton with the flow of water. The VAM2D model is a variably-saturated, finite element groundwater flow and solute transport model in two-dimensions. It can handle only single-phase flow and assumes that solute can be dissolved in water at any ratio. This is valid if the leaking rate of disulfoton is low and the soil water content is high, such that most of the leaking disulfoton will either dissolve in water or absorb onto soil particles. Unlike the SWANFLOW model, hydraulic properties of most geologic materials required by the VAM2D model are better characterized so that uncertainty of the simulation results are diminished. A two-dimensional cross-section from ground surface to the uppermost aquifer will be selected for simulation.

The SWANFLOW and VAM2D models do not consider the surface processes and interaction between climate and root-zone water balance, therefore the SHAW model (Flerchinger and Saxton, 1989) will be used to evaluate percolation, runoff and evapotranspiration. Long term representative climatic data from the nearby Burley weather station will be applied in the simulations. As described previously, percolation water may serve as an influential driving force for the chemicals to travel downward and laterally at the landfill site. Therefore, the simulated percolation data will be introduced to both the SWANFLOW and VAM2D simulations as influx boundary conditions. Vertical contaminant transport in the near surface vadose zone can also be simulated with the SHAW model, which provides a qualitative comparison with the results from VAM2D. However, SHAW has the similar limitations as VAM2D, i.e., single phase flow and unlimited water solubility.

***Data and Assumptions*:** Although disulfoton has a short half-life of 19 days, the major degradation mechanism under pH and moisture conditions at the Murtaugh site is oxidation, which produces metabolites as toxic as disulfoton itself. Therefore, scenarios with no degradation will be hypothesized in the simulations. Chemical adsorption onto the soil particles will be considered. The octanol-water partition coefficient, log(Kow)=4.02, will be used to calculate the organic carbon partition coefficient (Koc) and the distribution coefficient (Kd) for different soils. For example, Kd for the loamy soil with a total organic carbon of 0.38 percent was estimated to be 6.1 cm^3/g. Longitudinal dispersivities of 0.5 and 5 ft are appropriate for the scale-dependent contaminant transport simulations of SHAW and VAM2D, respectively. Hydraulic properties of the loamy soil obtained from laboratory analysis are given in Table 1. Because contaminant transport in the basalt formation will be simulated with VAM2D, hydraulic properties of fractured basalt and dense basalt measured in the Snake River Plain Aquifer near INEL and recommended by WASTREN will be adopted. Multiphase characteristic data of NAPL flow for the soils at the Murtaugh landfill are not available and will be derived from the water retention curve using the scaling technique. The volume and concentration of chemicals and the conditions of the buried containers in disposal trenches will be provided by WASTREN field investigations. Because the caliche layer varies from scattered broken pieces to consolidated hard layer underlying the Murtaugh landfill, scenarios with and without this layer will be hypothesized in the simulations.

Benchmarking of Simulation Models

A benchmarking process has been conducted to ensure the quality of the three simulation models described above. To do this, contaminant transport at the Murtaugh landfill site was simplified to an one-dimensional unsaturated flow and transport problem. A homogeneous soil profile was selected from the ground surface to the top of the basalt formation (25-ft deep) with no caliche layer in the profile. Hydraulic properties of the loamy soil given in Table 1 were used and degradation was not considered in the simulations. Ten-year simulations were performed with a 5-year leaking period and a 5-year redistribution period. Chemical with a concentration of 12,000 ppm was assumed to leak into the soil from 16 ft to 20 ft deep at a constant rate of 1.366×10^{-4} ft^3/day. No flow boundary was set on the ground surface and a constant head of -25 ft was applied to the bottom of the simulation domain. Figure 4 shows the perfect match of matric potential profiles between SHAW and SOILSIM at the end of the 10-year simulation and Figure 5 gives the comparison of concentrations at the first year after leaking. Reasonable matches were found between the two models.

Considering multiphase flow, the 1.366×10^{-4} ft^3/day leaking rate at 12,000 ppm used in the simulation contained small volume of NAPL. SWANFLOW, therefore, predicted very low NAPL saturations in the leaking zone from 16 ft to 20 ft. No NAPL flow took place because gravitational force was unable to drive this residual NAPL to move downward. In fact, fairly large amount of this residual disulfoton would be dissolved in water and the transport would occur by processes simulated by the VAM2D and SHAW models.

Preliminary Simulations

Based upon the knowledge from field investigations, preliminary simulations for contaminant transport at the Murtaugh site were performed with the three models described above. However, only brief simulation processes and results were presented in this report. A total number of 23,000 canisters was assumed to be buried in the disposal trenches. Each canister contained 2.5 gallon of disulfoton with a concentration of 12,000 ppm. Containers were assumed to fail over a five-year period, during which all the chemicals leaked into trenches at constant rates.

For the SHAW model simulation, the one-dimensional soil profile was selected from the ground surface to the top of fractured basalt (25 ft) without presence of caliche layer in the loamy soil. Long-term representative climatic data from the nearby Burley Weather Station were applied to evaluate evapotranspiration, runoff, and deep percolation. Figure 6 shows the simulated water balance on the Murtaugh landfill ground surface. No deep percolation was predicted due to the high potential evapotranspiration on the site. Contaminant transport was simulated with considerations of dispersion, diffusion, and adsorption. Concentration profile at the end of the 5-year leaking period is shown in Figure 7, where a maximum concentration of about 60 ppm exists at depths between 10 and 20 ft.

The two-dimensional soil profile for VAM2D simulation was selected from the ground surface to the uppermost aquifer, and the north and south boundaries of the 16-ha landfill site. Different geologic materials, such as the loamy soil, caliche layer, fractured basalt, dense basalt and interflows, were included in the soil profile. Because the SHAW model predicted no deep percolation, a no flow boundary condition was set on the top of the simulation domain. Constant leaking rates of disulfoton were introduced to bottom of trenches as influx boundary condition. Similar to the SHAW simulation, dispersion, diffusion, and adsorption were considered. Figure 8 shows the concentration contours at the end of the 5-year leaking period. A maximum concentration of 100 ppm is predicted at the contaminant plume center.

The two-dimensional SWANFLOW simulation was conducted from the ground surface to the top of fractured basalt and the north and south boundaries of the 16-ha landfill site. Caliche layer was not considered. A constant head of -25 ft was assumed to exist at the bottom of the simulation domain. Disulfoton (NAPL) was introduced to the bottom of trenches at constant rates. Because no mass transfer is considered between NAPL and water phases, pure disulfoton exists in the soil pore space at varying saturation. Figure 9 shows the NAPL saturation contour within the simulation domain at the end of the 5-year leaking period. A maximum NAPL saturation of 0.7 percent is predicted from the simulation.

Summary

This report briefly described the background and hydrogeologic conditions of the Murtaugh landfill, and situation of the buried contaminants. Owing to the complexity of the geologic materials, contaminant properties, and restrictions of existing simulation models, a combination of three models will be used to evaluate the fate and migration of chemicals at the Murtaugh landfill site. Data required by the models and assumptions for the simulations were presented and discussed. To ensure the quality of simulation, benchmarking processes were conducted for the three simulation models. Based upon the knowledge from field investigations, preliminary simulations for contaminant transport at the Murtaugh landfill were performed with the three models proposed. Additional modeling will be conducted when further information on the extent of buried contaminants is available.

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Table 1. Hydraulic Properties of Loamy Soil from Murtaugh Landfill

Saturated hydraulic conductivity (ft/day)	2.040
Dry Bulk Density (g/cm^3)	1.280
Porosity (%)	0.502
Residual Water Content (%)	0.120
Air Entry Pressure (ft H_2O)	-3.280
n	3.510
α (ft^{-1})	0.750
β	1.470

n, α, and β are the unsaturated hydraulic parameters for the Van Genuchten Equation.

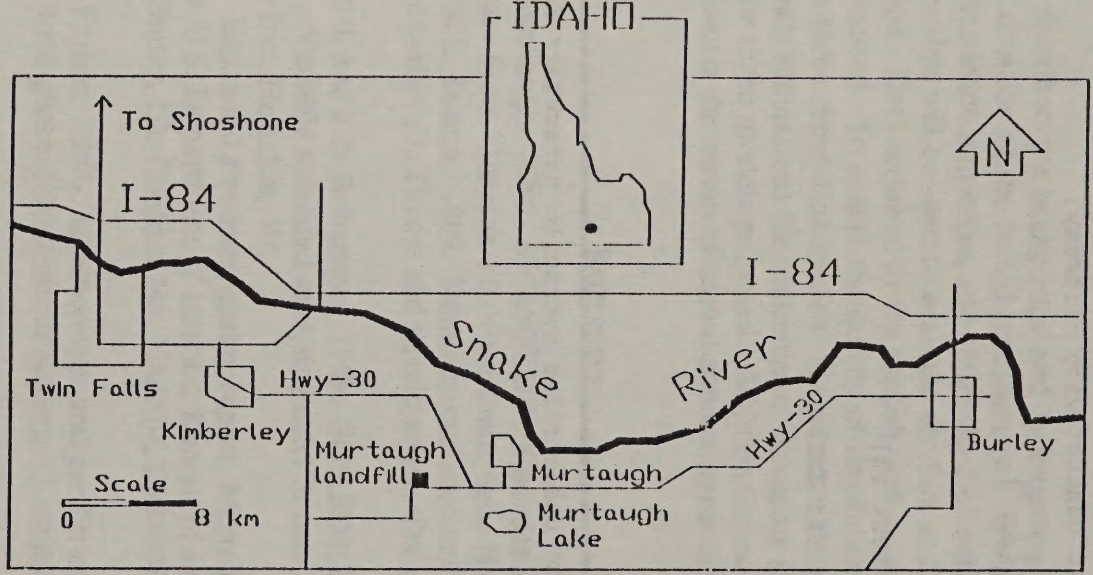

Figure 1. Geographical location of Murtaugh Landfill.

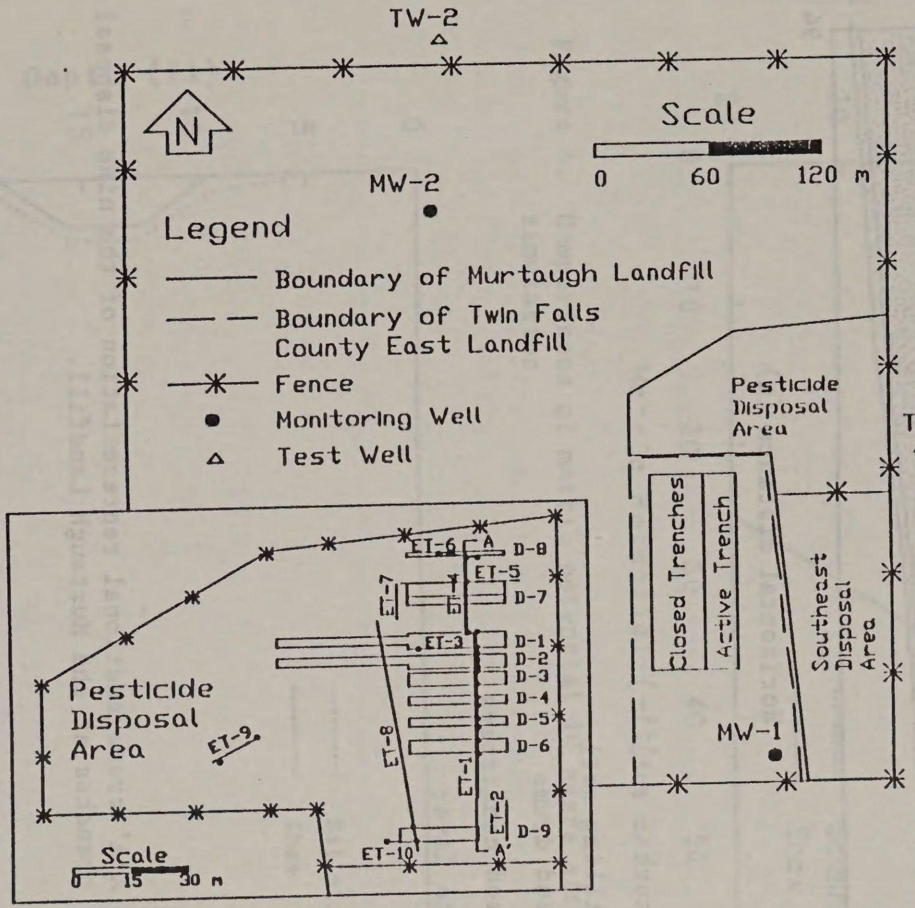

Figure 2. Trench layout at the Murtaugh Landfill within the 40-acre fenced area.

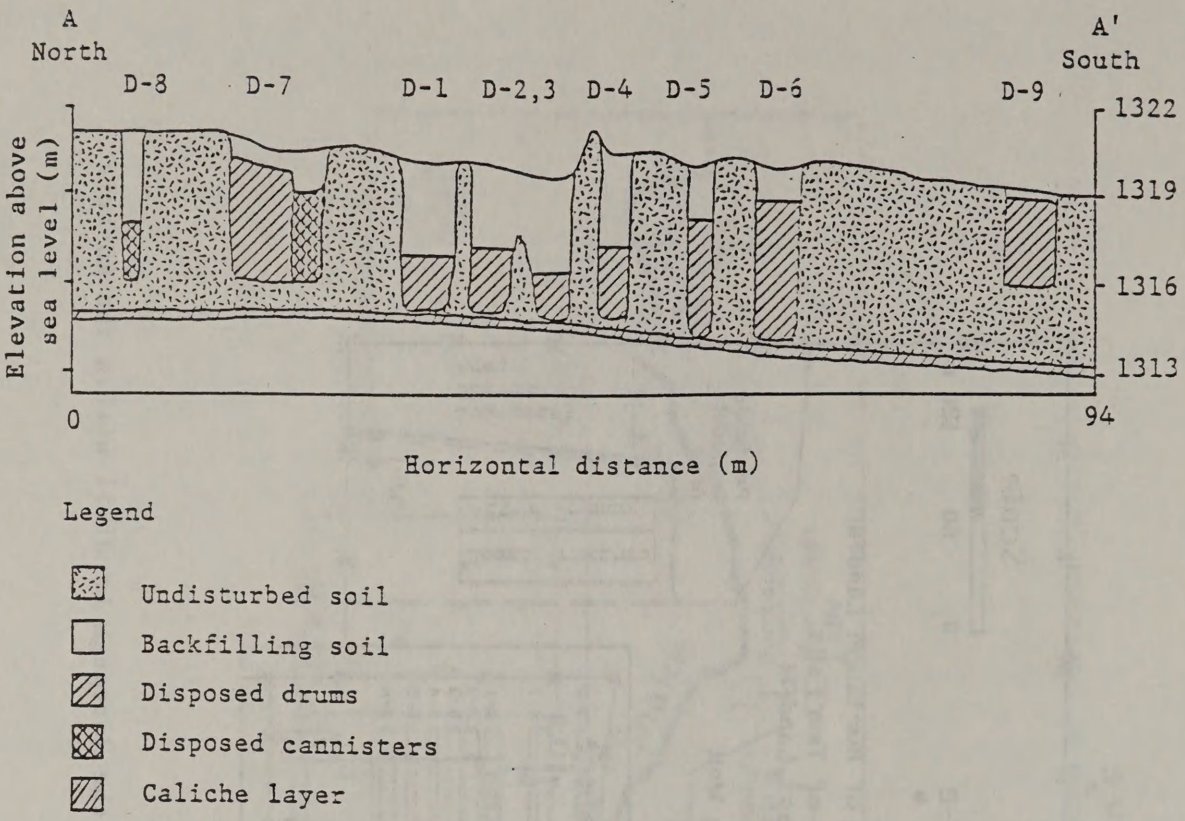

Figure 3. A-A' cross-sectional representation of the nine disposal trenches at the Murtaugh Landfill.

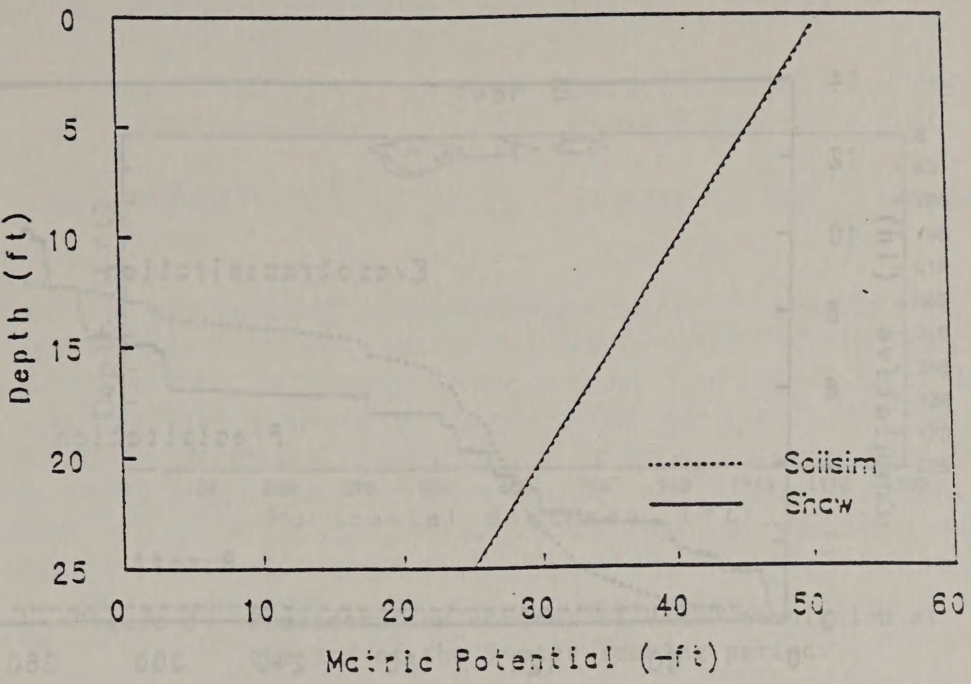

Figure 4. Comparisons of matric potential 10 years after simulation.

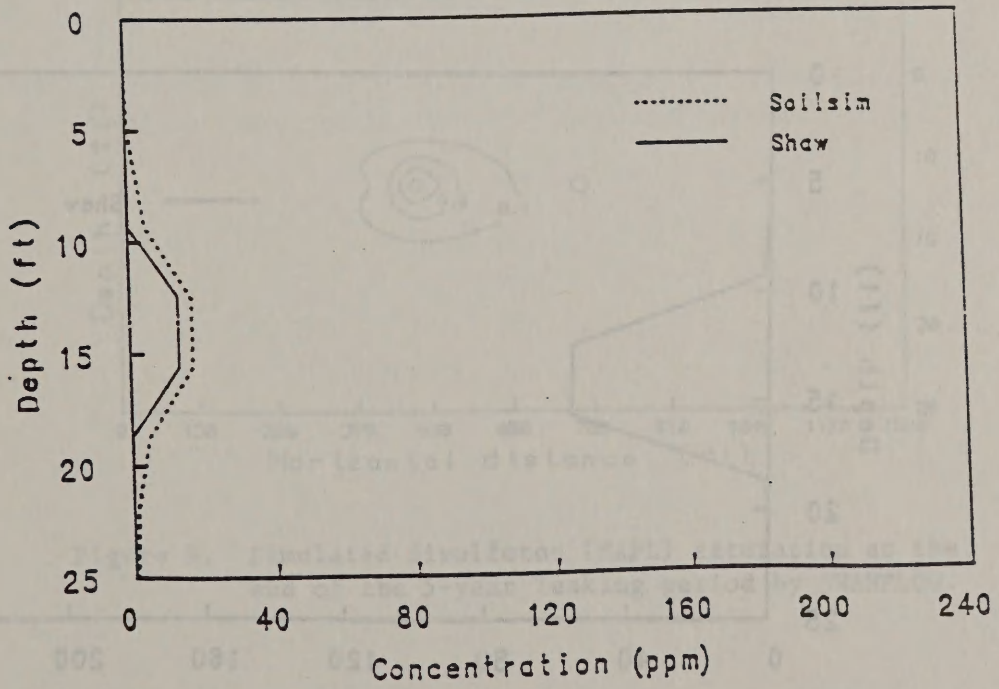

Figure 5. Comparisons of concentration profile 1 year after simulation.

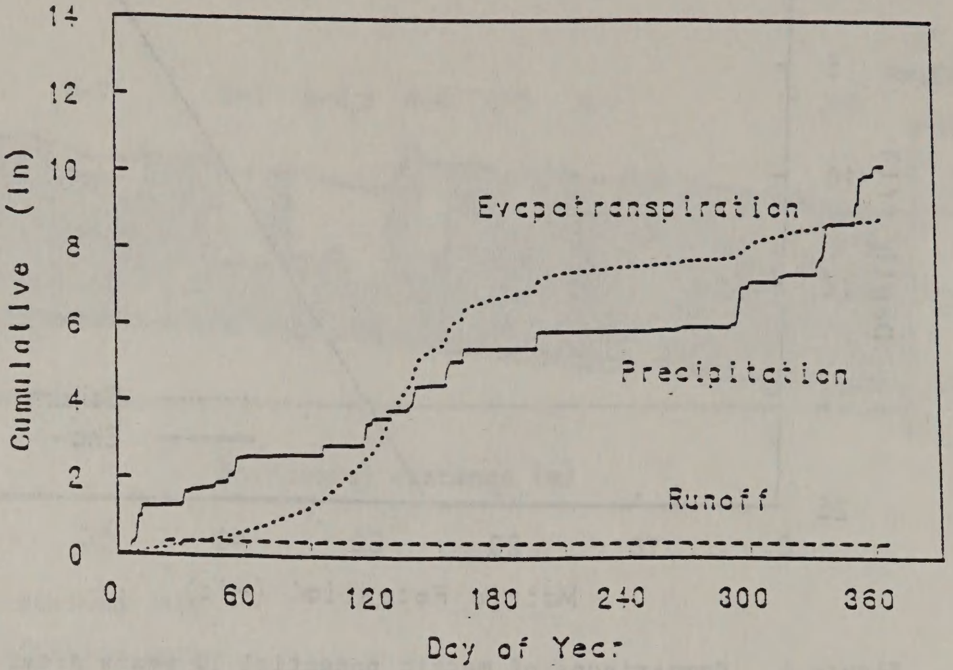

Figure 6. Cumulative evapotranspiration, precipitation and runoff simulated for a typical year.

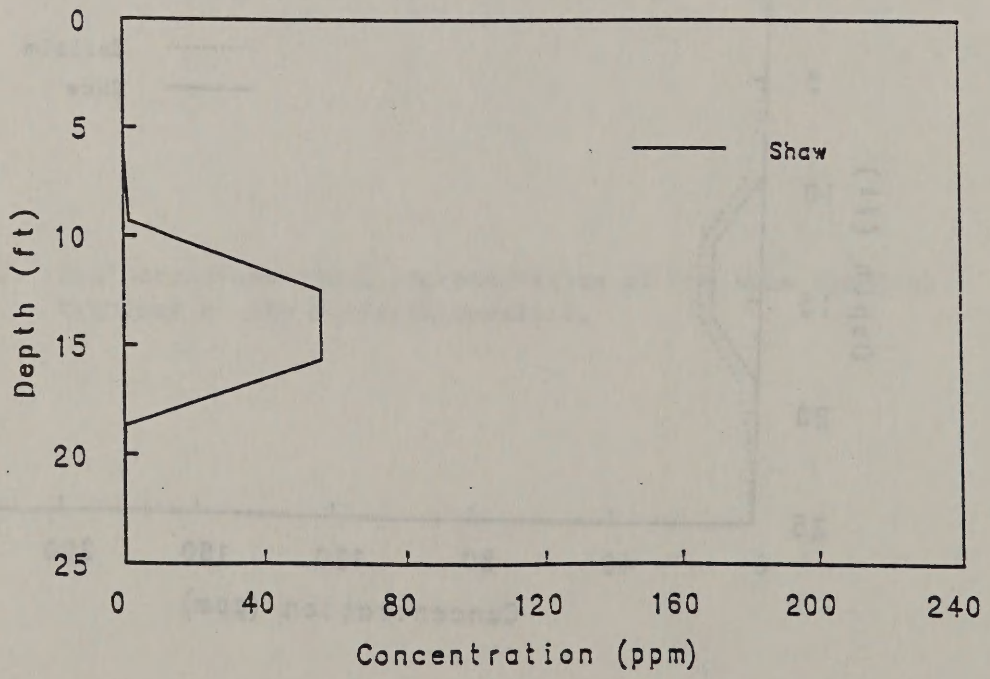

Figure 7. Concentration profile of SHAW simulation at the end of the 5-year leaking period.

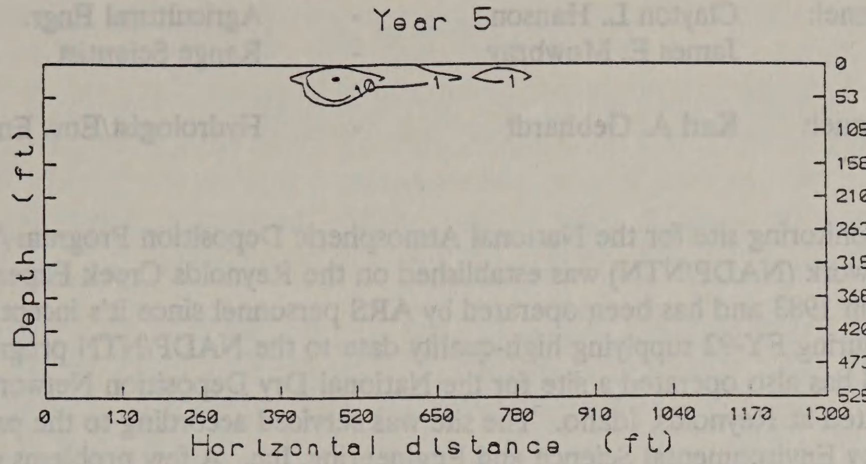

Figure 8. Concentration contour of VAM2D simulation at the end of the 5-year leaking period.

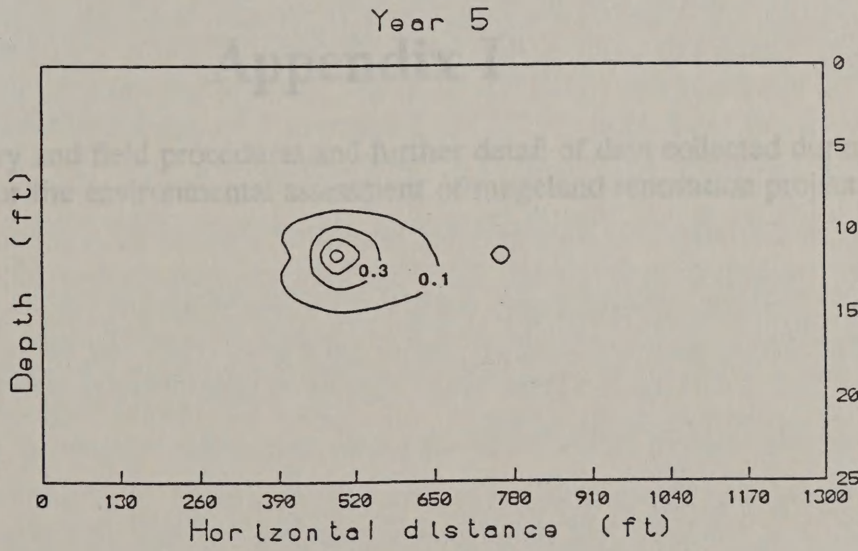

Figure 9. Simulated disulfoton (NAPL) saturation at the end of the 5-year leaking period by SWANFLOW.

7. NATIONAL ATMOSPHERIC DEPOSITION PROGRAM

ARS Personnel: Clayton L. Hanson - Agricultural Engr.
James E. Mowbray - Range Scientist

BLM Personnel: Karl A. Gebhardt - Hydrologist/Env. Engr.

A monitoring site for the National Atmospheric Deposition Program / National Trends Network (NADP/NTN) was established on the Reynolds Creek Experimental Watershed in 1983 and has been operated by ARS personnel since it's inception. The site continued during FY-92 supplying high-quality data to the NADP/NTN program.

ARS has also operated a site for the National Dry Deposition Network Monitoring System located at Reynolds, Idaho. The site was serviced according to the procedures developed by Environmental Science and Engineering, Inc. A few problems with the system were encountered during the year which required a considerable amount of additional time during the weekly system checks. Very little data was lost throughout the year for which the site operator was commended. In September 1990, the site was expanded and set up as a co-located site with two complete sets of monitoring instrumentation. This was done to check the operation of the original system.

Appendix I

Additional laboratory and field procedures and further detail of data collected during FY-90, FY-91 and FY-92 for the environmental assessment of rangeland renovation project.

LABORATORY AND FIELD PROCEDURES

Permanent Plots and Transects

On each sample plot within each treatment replication (Figures 2.2-2.10), 10 locations are randomly selected. For the Amazon and Disk Chain plots, this includes five interspaces and five furrows. At each location, soil temperature is taken at a 2 cm depth using a thermocouple thermometer. Also at each location, the average of three readings are recorded for the shear vane (using a Torvane) and penetrometer.

***Bulk Density and % Moisture*:** An opened end core sampler is used to remove a soil sample 3.0 cm deep with a volume of 67.1089 cm^3. Ten samples are taken per plot. Samples are oven dried at 105° C for 24 hours and weighed. Bulk density is determined as the dry weight divided by the constant volume. Percent moisture is determined by the moisture divided by the dry weight times 100.

***Wet Aggregate Stability*:** Ten samples are taken per plot and kept refrigerated until samples are to be run. The single sieve procedure (Kemper, 1986) is used to determine the resistance of the aggregates to breakdown when sieved in water. Air dry soil is sieved to collect aggregates between 1.0 and 2.0 mm diameter. Two 4 g soil samples are weighed into 2 sieves (24 mesh/cm). They are prepared for sieving by wetting slowly using a mist humidifier (up to 30% moisture - adjusted for 2% moisture in air dry soil). Samples are agitated in individual tins with deionized water for three minutes. The sieves are removed and placed in individual tins with 0.2% NaHMP to remove the soil from the sand particles. Tins and sieves are oven dried (105° C) and weighed. Wet aggregate stability is calculated by the ratio of the stable aggregates to unstable aggregates.

***Percent Organic Carbon*:** The Walkley-Black procedure (Nelson and Sommers, 1986) is used to determine percent organic carbon. For FY-90, 10 soil samples were collected once per year from each treatment replication. For FY-91, a composite of 10 soil samples per treatment replication were collected on each sample date. Each soil sample is air dried, ground, and passed through a 0.5mm sieve. Potassium dichromate is used as the reducing agent and ferrous sulfate as the titrant.

***Particle Size Analysis*:** The hydrometer method (Bouyoucos, 1962) is used to determine particle size. For FY-90, 10 soil samples were collected once per year from each treatment replication. For FY-91, a composite of 10 soil samples per treatment replication were collected on each sample date. Samples are first air dried and sieved for rocks greater than 2 mm. Samples (40 g) are pretreated overnight with 5% NaHMP and then mechanically dispersed. Sand, silt, and clay are determined after taking readings over a 24 hour period.

***Surface Roughness and Cover*:** Canopy (standing vegetation) and surface cover (grass, forb, moss, litter, rock, or bare ground) are measured by a vertical point frame consisting of 60 points along 8 permanent transects for a total of 480 points per treatment replication. Surface roughness along each transect is determined by computing the standard deviation of pin heights. Surface roughness for each treatment is the pooled standard deviation of the 1440 points within each replication.

Rainfall Simulation Plots

***Surface Roughness and Cover*:** Prior to the rainfall simulation, canopy and surface cover are measured as for permanent transects with the exception that each plot consists of 10 transects for a total of 600 points per plot per treatment replication. Surface roughness along each of the 10 transects is determined by computing the standard deviation of pin heights. Surface roughness for each treatment is the pooled standard deviation of the 3600 points within each replication.

***Rainfall Simulation and Runoff Collection*:** A rotating boom rainfall simulator is used on paired plots (3.05 m x 10.67 m) within each treatment per rep. Two rainfall simulations are run over two days. The Dry Run consists of an hour of simulated rainfall under existing antecedent moisture conditions. This is followed 24 hours later by the Wet Run which is for 0.5 hours at or near field capacity soil moisture. Plot runoff is continuously recorded through a 10 cm dropbox weir equipped with an ISCO Bubbler Flow Meter. Sediment samples are collected when runoff begins and continued every 2 minutes as runoff increases to a constant rate, thereafter every 4 minutes.

***Rainfall Measurement*:** The simulator water pressure is adjusted to obtain the design rainfall intensity of 6.35 cm/hr. Six tru-check rain gauges per plot are used to measure the simulated rainfall.

***Sediment*:** Sediment samples are weighed to determine volume and allowed to settle. The samples are analyzed to determine sediment concentrations (mg/l) by decanting and then drying the sediment at 105° C. This value is processed with water level records to determine runoff and soil loss for each run.

***Soil Measurements*:** Samples locations are determined by treatment with the Control being randomly selected, and the Amazon and Disk Chain samples equally split between interspace and furrow.

Just prior to rainfall simulation adjacent to each plot soil measurements are as follows: 1) Bulk density/Soil moisture samples (4/plot at 3.0 cm); 2) Penetrometer and Shear vane (4/plot from mean of 3 readings); 3) Temperature at 2 cm depth (4/plot); and 4) Aggregate stability samples (4/plot at 3.0 cm).

Just prior to the wet run adjacent to each plot, soil moisture samples are taken (4/plot at 3.0 cm).

Twenty-four hours after the wet run within each plot, the following measurements are taken: 1) Bulk density/Soil moisture (4/plot at 3.0 cm); 2) Penetrometer and Shear vane (4/plot from mean of 3 readings); 3) Temperature at 2 cm depth (4/plot); and 4) Aggregate stability sample (4/plot at 3.0 cm). Additional samples taken randomly, irregardless of interspace or furrow, are: 1) Organic carbon/Texture (FY-90 2 samples/plot at 3 cm, FY-91 1 composite of 4 samples/plot at 3cm); 2) Below ground biomass (2/plot at 3.0 cm); and 3) Plant biomass (five 1 ft^2 subsample/plot).

Root Mass: Two 3.0 cm deep surface samples are taken per rain simulation plot using the opened end core sampler. Soil cores are washed and roots are removed. Roots are dried at 105° C and weighed, then ashed in a muffle furnace at 610° C and weighed. Data is reported on an ash free weight.

Plant Samples: Plants are clipped at the surface and plant biomass collected from five 1 ft^2 sections per rainfall simulation plot. Samples are divided into the categories of litter, forbs, crested wheat, and other grasses. Samples are oven dried at 60^o C. Results are reported as kilograms dry weight per hectare.

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ADDITIONAL TABLES AND FIGURES

Table AI.1. Moisture, Bulk Density, Sheer Vane, and Penetrometer by Sampling Date (1989-1992). Data is presented for both Interspace (I) and Furrow (F). Greenstripping, Permanent Transects.

Moisture (%)*

	Control	Amazon			Disk Chain		
Dates	Avg.	I	F	Avg I + F	I	F	Avg I + F
11/20/89	7.57	8.82	7.89	8.35	7.02	7.28	7.15
01/09/90	21.00	20.28	19.20	19.74	18.21	19.37	18.79
02/07/90	16.30	18.24	18.11	18.18	15.70	16.05	15.88
03/02/90	10.35	13.36	12.30	12.83	14.78	14.56	14.67
04/05/90	2.33	3.07	3.23	3.15	4.42	4.57	4.49
05/02/90	9.45	10.91	11.44	11.18	13.08	13.42	13.25
06/04/90	10.77	10.07	10.42	10.25	11.36	11.60	11.48
08/01/90	1.64	1.64	1.80	1.72	1.66	2.04	1.85
10/04/90	1.89	2.09	2.43	2.26	2.41	2.50	2.45
11/05/90	9.62	9.25	11.13	10.19	9.80	11.07	10.44
12/03/90	7.92	6.53	7.25	6.89	6.65	7.22	6.93
01/05/91	13.15	9.26	8.08	8.67	10.23	10.05	10.14
02/01/91	23.23	25.56	22.88	24.22	21.65	25.27	23.46
03/05/91	19.61	19.56	18.80	19.18	21.19	21.36	21.28
03/29/91	7.99	13.36	14.29	13.83	12.27	12.25	12.26
05/01/91	3.47	4.47	4.93	4.70	4.88	5.89	5.39
06/03/91	3.66	4.44	4.12	4.28	3.55	3.70	3.62
08/01/91	1.44	1.26	1.24	1.25	1.93	2.08	2.01
10/01/91	2.36	2.28	2.38	2.33	2.19	2.21	2.20
11/05/91	14.80	15.34	15.01	15.17	16.82	17.12	16.97
12/06/91	24.02	22.39	23.02	22.71	20.59	22.25	21.42
01/02/92	9.30	22.04	25.52	23.78	14.95	16.05	15.50
02/01/92	16.91	20.86	20.19	20.52	16.07	16.96	16.51
03/05/92	13.18	16.12	17.98	17.05	11.97	12.40	12.18
04/02/92	4.12	4.59	5.06	4.83	6.52	6.38	6.45
05/08/92	2.78	2.79	3.08	2.94	2.97	3.14	3.06
06/02/92	1.58	1.60	1.71	1.65	1.99	2.03	2.01

Bulk Density (g/cm3)*

	Control	Amazon			Disk Chain		
Dates	Avg.	I	F	Avg I + F	I	F	Avg I + F
11/20/89	1.25	1.11	1.09	1.10	1.12	1.14	1.13
01/09/90	1.17	1.08	1.08	1.08	0.97	1.10	1.04
02/07/90	1.10	1.05	0.95	1.00	0.95	1.05	1.00
03/02/90	1.18	1.23	1.22	1.22	1.04	1.06	1.05
04/05/90	1.27	1.34	1.31	1.33	1.21	1.23	1.22
05/02/90	1.18	1.17	1.24	1.21	1.11	1.13	1.12
06/04/90	1.11	1.28	1.27	1.28	1.10	1.15	1.13
08/01/90	1.24	1.22	1.23	1.23	1.18	1.20	1.19
10/04/90	1.27	1.22	1.14	1.18	1.19	1.15	1.17
11/05/90	1.16	1.26	1.16	1.21	1.10	1.12	1.11
12/03/90	1.10	1.18	1.19	1.18	1.17	1.15	1.16
01/05/91	1.03	1.22	1.22	1.22	1.03	1.02	1.02

Table AI.1. Cont.

Bulk Density (g/cm3)*

	Control	Amazon			Disk Chain		
Dates	Avg.	I	F	Avg I + F	I	F	Avg I + F
02/01/91	1.03	1.03	0.92	0.97	1.08	0.96	1.02
03/05/91	1.24	1.12	1.13	1.13	0.91	1.00	0.95
03/29/91	1.15	1.14	1.00	1.07	1.00	0.96	0.98
05/01/91	1.19	1.10	1.10	1.10	1.09	1.11	1.10
06/03/91	1.19	1.15	1.13	1.14	1.13	1.13	1.13
08/01/91	1.26	1.31	1.33	1.32	1.18	1.18	1.18
10/01/91	1.34	1.27	1.23	1.25	1.19	1.20	1.20
11/05/91	1.24	1.09	1.08	1.08	1.03	1.03	1.03
12/06/91	1.25	1.11	1.02	1.06	1.19	1.13	1.16
01/02/92	1.14	1.02	0.91	0.96	0.95	0.93	0.94
02/01/92	1.10	1.06	0.94	1.00	1.01	1.03	1.02
03/05/92	1.19	1.11	0.99	1.05	1.01	1.07	1.04
04/02/92	1.25	1.12	1.15	1.14	1.06	1.01	1.03
05/08/92	1.30	1.06	1.11	1.09	1.12	1.10	1.11
06/02/92	1.24	1.17	1.06	1.11	1.10	1.11	1.10

Sheer Vane(kg/cm2)**

	Control	Amazon			Disk Chain		
Dates	Avg.	I	F	Avg I + F	I	F	Avg I + F
11/20/89	0.23	0.25	0.09	0.17	0.01	0.05	0.03
01/09/90	0.20	0.19	0.11	0.15	0.09	0.13	0.11
02/07/90	Frozen Soil -- Unable to Sample						
03/02/90	0.16	0.19	0.12	0.16	0.01	0.00	0.01
04/05/90	0.14	0.13	0.08	0.11	0.05	0.06	0.05
05/02/90	0.14	0.18	0.13	0.15	0.11	0.12	0.11
06/04/90	0.23	0.17	0.14	0.16	0.10	0.14	0.12
08/01/90	0.16	0.10	0.08	0.09	0.09	0.11	0.10
10/04/90	0.19	0.08	0.08	0.08	0.04	0.06	0.05
11/05/90	0.21	0.23	0.17	0.20	0.15	0.21	0.18
12/03/90	Frozen Soil -- Unable to Sample						
01/05/91	Frozen Soil -- Unable to Sample						
02/01/91	Frozen Soil -- Unable to Sample						
03/05/91	0.23	0.14	0.16	0.15	0.10	0.12	0.11
03/29/91	0.13	0.14	0.19	0.16	0.05	0.08	0.06
05/01/91	0.10	0.10	0.10	0.10	0.09	0.11	0.10
06/03/91	0.10	0.10	0.12	0.11	0.07	0.09	0.08
08/01/91	0.09	0.09	0.11	0.10	0.06	0.06	0.06
10/01/91	0.06	0.09	0.10	0.10	0.09	0.08	0.09
11/05/91	0.09	0.16	0.19	0.17	0.07	0.08	0.08
12/06/91	0.07	0.14	0.15	0.15	0.13	0.08	0.10
01/02/92	Frozen Soil -- Unable to Sample						
02/01/92	Frozen Soil -- Unable to Sample						
03/05/92	----	0.18	0.20	0.19	0.10	0.09	0.10
04/02/92	0.08	0.14	0.18	0.16	0.07	0.07	0.07
05/08/92	0.08	0.13	0.13	0.13	0.05	0.05	0.05
06/02/92	0.18	0.09	0.09	0.09	0.11	0.14	0.13

Table AI.1.

Penetrometer (kg/cm2)**

	Control	Amazon			Disk Chain		
Dates	Avg.	I	F	Avg I + F	I	F	Avg I + F
11/20/89	1.82	1.70	0.67	1.18	0.03	0.29	0.16
01/09/90	1.03	0.55	0.29	0.42	0.19	0.28	0.24
02/07/90	Frozen Soil -- Unable to Sample						
03/02/90	1.64	0.50	0.40	0.45	0.04	0.06	0.05
04/05/90	1.55	0.72	0.53	0.63	0.29	0.51	0.40
05/02/90	1.38	1.27	0.71	0.99	0.25	0.46	0.36
06/04/90	1.29	1.10	0.91	1.01	0.34	0.58	0.46
08/01/90	1.19	0.96	0.42	0.69	0.43	0.49	0.46
10/04/90	1.18	0.97	0.30	0.63	0.34	0.33	0.34
11/05/90	1.45	1.60	0.82	1.21	0.87	0.79	0.83
12/03/90	Frozen Soil -- Unable to Sample						
01/05/91	Frozen Soil -- Unable to Sample						
02/01/91	Frozen Soil -- Unable to Sample						
03/05/91	0.27	0.64	0.64	0.64	0.20	0.26	0.23
03/29/91	0.85	1.15	0.99	1.07	0.27	0.24	0.26
05/01/91	0.56	0.72	0.44	0.58	0.44	0.77	0.60
06/03/91	0.48	0.55	0.53	0.54	0.23	0.40	0.32
08/01/91	0.49	0.65	0.62	0.63	0.17	0.49	0.33
10/01/91	0.80	0.74	0.66	0.70	0.69	0.56	0.63
11/05/91	0.52	0.97	0.85	0.91	0.31	0.29	0.30
12/06/91	0.23	0.35	0.34	0.35	0.25	0.24	0.25
01/02/92	Frozen Soil -- Unable to Sample						
02/01/92	Frozen Soil -- Unable to Sample						
03/05/92	0.39	0.68	0.62	0.65	0.69	0.60	0.65
04/02/92	0.69	0.94	0.97	0.95	0.77	0.74	0.75
05/08/92	0.73	0.71	0.79	0.75	0.59	0.81	0.70
06/02/92	0.56	0.54	0.54	0.54	0.37	0.52	0.44

* n=30
** n=90

Table AI.2 (A-AA). Moisture, Bulk Density, Sheer Vane, and Penetrometer. Data is Presented by Replication (Rep) for both Interspace (I) and Furrow (F) Locations. The Average of I and F (avg) is also given. Greenstripping, Permanent Transects.

A. Sampled November 20-21, 1989

Moisture (%)*

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	8.09	7.01	7.62	7.57
Amazon	I	9.10	8.98	8.36	8.82
	F	8.12	7.83	7.72	7.89
	avg	8.61	8.40	8.04	8.35
Disk Chain	I	8.65	4.99	7.42	7.02
	F	7.75	6.56	7.54	7.28
	avg	8.20	5.77	7.48	7.15

Bulk Density (g/cm3)*

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	1.20	1.24	1.32	1.25
Amazon	I	1.20	1.04	1.10	1.11
	F	1.13	1.08	1.07	1.09
	avg	1.16	1.06	1.08	1.10
Disk Chain	I	1.06	1.26	1.04	1.12
	F	1.16	1.14	1.12	1.14
	avg	1.11	1.20	1.08	1.13

Sheer Vane (kg/cm2)**

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	0.28	0.24	0.19	0.23
Amazon	I	0.27	0.25	0.24	0.25
	F	0.15	0.06	0.05	0.09
	avg	0.21	0.16	0.15	0.17
Disk Chain	I	0.01	0.01	0.00	0.01
	F	0.06	0.03	0.05	0.05
	avg	0.03	0.02	0.03	0.03

Penetrometer (kg/cm2)**

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	2.37	1.90	1.21	1.82
Amazon	I	2.20	1.46	1.44	1.70
	F	1.44	0.15	0.41	0.67
	avg	1.82	0.81	0.93	1.18
Disk Chain	I	0.05	0.03	0.00	0.03
	F	0.46	0.20	0.20	0.29
	avg	0.26	0.12	0.10	0.16

* n=10/rep

** n=30/rep

Table AI.2 (A-AA). Cont.

B. Sampled January 9, 1990

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
			Moisture (%)*		
Control	—	22.45	20.23	20.30	21.00
Amazon	I	22.23	16.07	22.53	20.28
	F	21.00	15.79	20.82	19.20
	avg	21.61	15.93	21.68	19.74
Disk Chain	I	19.63	15.78	19.22	18.21
	F	20.15	17.43	20.54	19.37
	avg	19.89	16.61	19.88	18.79
			Bulk Density (g/cm3)*		
Control	—	1.23	1.11	1.18	1.17
Amazon	I	1.02	1.27	0.96	1.08
	F	1.07	1.14	1.04	1.08
	avg	1.05	1.20	1.00	1.08
Disk Chain	I	0.98	0.99	0.95	0.97
	F	1.19	1.19	0.92	1.10
	avg	1.08	1.09	0.93	1.04
			Sheer Vane (kg/cm2)**		
Control	—	0.21	0.17	0.21	0.20
Amazon	I	0.16	0.19	0.22	0.19
	F	0.10	0.09	0.15	0.11
	avg	0.13	0.14	0.19	0.15
Disk Chain	I	0.10	0.09	0.09	0.09
	F	0.13	0.17	0.10	0.13
	avg	0.11	0.13	0.09	0.11
			Penetrometer (kg/cm2)**		
Control	—	1.20	1.03	0.86	1.03
Amazon	I	0.78	0.49	0.39	0.55
	F	0.35	0.35	0.18	0.29
	avg	0.57	0.42	0.29	0.42
Disk Chain	I	0.23	0.17	0.18	0.19
	F	0.31	0.35	0.18	0.28
	avg	0.27	0.26	0.18	0.24

* n=10/rep
** n=30/rep

Table AI.2 (A-AA). Cont.

C. Sampled February 7, 1990

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
		Moisture (%)*			
Control	—	14.84	16.62	17.44	16.30
Amazon	I	17.81	19.09	17.82	18.24
	F	15.52	20.02	18.81	18.11
	avg	16.66	19.56	18.31	18.18
Disk Chain	I	14.17	14.88	18.04	15.70
	F	13.89	15.86	18.40	16.05
	avg	14.03	15.37	18.22	15.88
		Bulk Density (g/cm3)*			
Control	—	1.20	1.08	1.03	1.10
Amazon	I	1.07	0.98	1.09	1.05
	F	0.98	0.93	0.94	0.95
	avg	1.02	0.95	1.01	1.00
Disk Chain	I	1.03	0.96	0.86	0.95
	F	1.13	1.09	0.93	1.05
	avg	1.08	1.02	0.90	1.00
		Sheer Vane (kg/cm2)**			
Control	—	Frozen Soil - unable to sample			
Amazon	I				
	F				
	avg				
Disk Chain	I				
	F				
	avg				
		Penetrometer (kg/cm2)**			
Control	—	Frozen Soil - unable to sample			
Amazon	I				
	F				
	avg				
Disk Chain	I				
Chain	F				
	avg				

* n=10/rep
**n=30/rep

Table AI.2 (A-AA). Cont.

D. Sampled March 2, 1990

Moisture (%)*

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	8.10	12.01	10.94	10.35
Amazon	I	14.54	16.19	9.36	13.36
	F	12.71	13.11	11.09	12.30
	avg	13.62	14.65	10.23	12.83
Disk Chain	I	16.54	13.91	13.90	14.78
	F	16.50	12.46	14.73	14.56
	avg	16.52	13.18	14.31	14.67

Bulk Density (g/cm3)*

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	1.22	1.19	1.14	1.18
Amazon	I	1.28	1.08	1.32	1.23
	F	1.18	1.19	1.29	1.22
	avg	1.23	1.13	1.30	1.22
Disk Chain	I	1.02	1.09	1.02	1.04
	F	1.07	1.12	1.00	1.06
	avg	1.05	1.11	1.01	1.05

Sheer Vane (kg/cm2)**

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	0.15	0.18	0.14	0.16
Amazon	I	0.22	0.15	0.21	0.19
	F	0.14	0.07	0.15	0.12
	avg	0.18	0.11	0.18	0.16
Disk Chain	I	0.03	0.00	0.00	0.01
	F	0.01	0.00	0.00	0.00
	avg	0.02	0.00	0.00	0.01

Penetrometer (kg/cm2)**

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	1.74	1.77	1.43	1.64
Amazon	I	0.78	0.25	0.47	0.50
	F	0.16	0.21	0.85	0.40
	avg	0.47	0.23	0.66	0.45
Disk Chain	I	0.08	0.01	0.04	0.04
	F	0.10	0.04	0.03	0.06
	avg	0.09	0.03	0.04	0.05

* n=10/rep
** n=30/rep

Table AI.2 (A-AA). Cont.

E. Sampled April 5, 1990

Moisture (%)*

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	---	2.67	2.07	2.25	2.33
Amazon	I	2.60	2.85	3.76	3.07
	F	3.88	2.52	3.28	3.23
	avg	3.24	2.69	3.52	3.15
Disk Chain	I	6.69	3.81	2.76	4.42
	F	6.27	4.17	3.26	4.57
	avg	6.48	3.99	3.01	4.49

Bulk Density (g/cm3)*

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	---	1.22	1.32	1.27	1.27
Amazon	I	1.37	1.36	1.31	1.34
	F	1.23	1.31	1.40	1.31
	avg	1.30	1.33	1.35	1.33
Disk Chain	I	1.09	1.25	1.28	1.21
	F	1.13	1.30	1.27	1.23
	avg	1.11	1.28	1.27	1.22

Sheer Vane (kg/cm2)**

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	---	0.22	0.14	0.08	0.14
Amazon	I	0.15	0.11	0.13	0.13
	F	0.04	0.08	0.13	0.08
	avg	0.09	0.09	0.13	0.11
Disk Chain	I	0.02	0.03	0.10	0.05
	F	0.01	0.04	0.13	0.06
	avg	0.01	0.03	0.11	0.05

Penetrometer (kg/cm2)**

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	---	1.75	1.40	1.51	1.55
Amazon	I	0.51	0.41	1.26	0.72
	F	0.22	0.18	1.19	0.53
	avg	0.36	0.29	1.23	0.63
Disk Chain	I	0.36	0.11	0.38	0.29
	F	0.18	0.18	1.17	0.51
	avg	0.27	0.14	0.78	0.40

* n=10/rep
** n=30/rep

Table AI.2 (A-AA). Cont.

F. Sampled May 2, 1990

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
			Moisture (%)*		
Control	—	9.90	9.23	9.21	9.45
Amazon	I	14.11	9.68	8.96	10.91
	F	14.27	10.08	9.96	11.44
	avg	14.19	9.88	9.46	11.18
Disk Chain	I	11.91	12.88	14.46	13.08
	F	12.33	12.33	15.61	13.42
	avg	12.12	12.61	15.03	13.25
			Bulk Density (g/cm3)*		
Control	—	1.12	1.20	1.21	1.18
Amazon	I	0.96	1.26	1.30	1.17
	F	1.09	1.31	1.32	1.24
	avg	1.02	1.28	1.31	1.21
Disk Chain	I	1.08	1.19	1.06	1.11
	F	1.19	1.13	1.08	1.13
	avg	1.13	1.16	1.07	1.12
			Sheer Vane (kg/cm2)**		
Control	—	0.16	0.17	0.10	0.14
Amazon	I	0.20	0.18	0.15	0.18
	F	0.16	0.13	0.11	0.13
	avg	0.18	0.15	0.13	0.15
Disk Chain	I	0.15	0.09	0.09	0.11
	F	0.18	0.08	0.08	0.12
	avg	0.17	0.09	0.09	0.11
			Penetrometer (kg/cm2)**		
Control	—	1.52	1.48	1.15	1.38
Amazon	I	1.06	1.05	1.70	1.27
	F	0.40	0.26	1.48	0.71
	avg	0.73	0.65	1.59	0.99
Disk Chain	I	0.38	0.19	0.18	0.25
	F	0.88	0.32	0.19	0.46
	avg	0.63	0.25	0.18	0.36

* n=10/rep
** n=30/rep

Table AI.2 (A-AA). Cont.

G. Sampled June 4, 1990

			Moisture (%)*		
Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	13.52	7.96	10.82	10.77
Amazon	I	8.57	8.86	12.78	10.07
	F	10.59	7.69	12.99	10.42
	avg	9.58	8.28	12.89	10.25
Disk Chain	I	13.59	10.58	9.91	11.36
	F	12.91	11.67	10.23	11.60
	avg	13.25	11.13	10.07	11.48
			Bulk Density (g/cm3)*		
Control	—	0.99	1.26	1.09	1.11
Amazon	I	1.21	1.37	1.27	1.28
	F	1.12	1.42	1.26	1.27
	avg	1.17	1.39	1.27	1.28
Disk Chain	I	1.05	1.17	1.08	1.10
	F	1.06	1.19	1.20	1.15
	avg	1.06	1.18	1.14	1.13
			Sheer Vane (kg/cm2)**		
Control	—	0.29	0.22	0.19	0.23
Amazon	I	0.23	0.10	0.18	0.17
	F	0.18	0.12	0.12	0.14
	avg	0.21	0.11	0.15	0.16
Disk Chain	I	0.12	0.10	0.09	0.10
	F	0.12	0.11	0.19	0.14
	avg	0.12	0.11	0.14	0.12
			Penetrometer (kg/cm2)**		
Control	—	0.61	1.77	1.50	1.29
Amazon	I	1.08	1.02	1.21	1.10
	F	1.13	0.82	0.78	0.91
	avg	1.10	0.92	0.99	1.01
Disk Chain	I	0.21	0.19	0.63	0.34
	F	0.47	0.35	0.93	0.58
	avg	0.34	0.27	0.78	0.46

* n=10/rep
** n=30/rep

Table AI.2 (A-AA). Cont.

H. Sampled August 1, 1990

Moisture (%)*

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	1.85	1.16	1.90	1.64
Amazon	I	1.62	1.39	1.90	1.64
	F	1.83	1.65	1.94	1.80
	avg	1.73	1.52	1.92	1.72
Disk Chain	I	2.13	1.27	1.57	1.66
	F	2.63	1.82	1.69	2.04
	avg	2.38	1.54	1.63	1.85

Bulk Density (g/cm3)*

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	1.19	1.40	1.15	1.24
Amazon	I	1.18	1.31	1.19	1.22
	F	1.22	1.29	1.19	1.23
	avg	1.20	1.30	1.19	1.23
Disk Chain	I	1.11	1.25	1.17	1.18
	F	1.14	1.30	1.18	1.20
	avg	1.12	1.27	1.17	1.19

Sheer Vane (kg/cm2)**

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	0.17	0.17	0.15	0.16
Amazon	I	0.12	0.05	0.13	0.10
	F	0.08	0.06	0.10	0.08
	avg	0.10	0.06	0.11	0.09
Disk Chain	I	0.07	0.10	0.11	0.09
	F	0.08	0.14	0.12	0.11
	avg	0.08	0.12	0.12	0.10

Penetrometer (kg/cm2)**

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	1.45	1.41	0.71	1.19
Amazon	I	1.33	0.68	0.86	0.96
	F	0.37	0.56	0.35	0.42
	avg	0.85	0.62	0.61	0.69
Disk Chain	I	0.16	0.47	0.67	0.43
	F	0.18	0.65	0.65	0.49
	avg	0.17	0.56	0.66	0.46

* n=10/rep
** n=30/rep

Table AI.2 (A-AA). Cont.

I. Sampled October 4, 1990

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
			Moisture (%)*		
Control	—	2.35	1.70	1.61	1.89
Amazon	I	2.21	1.84	2.23	2.09
	F	2.70	2.10	2.48	2.43
	avg	2.45	1.97	2.35	2.26
Disk Chain	I	1.92	2.75	2.55	2.41
	F	2.92	2.41	2.16	2.50
	avg	2.42	2.58	2.36	2.45
			Bulk Density (g/cm3)*		
Control	—	1.18	1.33	1.28	1.27
Amazon	I	1.22	1.20	1.24	1.22
	F	1.14	1.11	1.16	1.14
	avg	1.18	1.16	1.20	1.18
Disk Chain	I	1.20	1.17	1.19	1.19
	F	1.15	1.16	1.15	1.15
	avg	1.17	1.16	1.17	1.17
			Sheer Vane (kg/cm2)**		
Control	—	0.15	0.24	0.17	0.19
Amazon	I	0.11	0.06	0.07	0.08
	F	0.07	0.09	0.07	0.08
	avg	0.09	0.07	0.07	0.08
Disk Chain	I	0.06	0.02	0.03	0.04
	F	0.09	0.03	0.07	0.06
	avg	0.08	0.02	0.05	0.05
			Penetrometer (kg/cm2)**		
Control	—	0.75	0.94	1.85	1.18
Amazon	I	1.40	0.57	0.93	0.97
	F	0.32	0.29	0.28	0.30
	avg	0.86	0.43	0.61	0.63
Disk Chain	I	0.71	0.15	0.17	0.34
	F	0.59	0.17	0.25	0.33
	avg	0.65	0.16	0.21	0.34

* n=10/rep
** n=30/rep

Table AI.2 (A-AA). Cont.

J. Sampled November 5, 1990

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
			Moisture (%)*		
Control	—	11.25	8.82	8.79	9.62
Amazon	I	10.59	9.61	7.54	9.25
	F	9.94	14.13	9.31	11.13
	avg	10.27	11.87	8.43	10.19
Disk Chain	I	10.34	8.78	10.30	9.80
	F	12.99	7.71	12.52	11.07
	avg	11.66	8.25	11.41	10.44
			Bulk Density (g/cm3)*		
Control	—	1.05	1.21	1.20	1.16
Amazon	I	1.33	1.08	1.36	1.26
	F	1.23	1.03	1.23	1.16
	avg	1.28	1.05	1.29	1.21
Disk Chain	I	1.07	1.21	1.03	1.10
	F	1.02	1.30	1.03	1.12
	avg	1.05	1.25	1.03	1.11
			Sheer Vane (kg/cm2)**		
Control	—	0.15	0.19	0.29	0.21
Amazon	I	0.20	0.20	0.29	0.23
	F	0.14	0.15	0.21	0.17
	avg	0.17	0.17	0.25	0.20
Disk Chain	I	0.21	0.14	0.11	0.15
	F	0.25	0.22	0.17	0.21
	avg	0.23	0.18	0.14	0.18
			Penetrometer (kg/cm2)**		
Control	—	0.73	1.57	2.05	1.45
Amazon	I	1.71	1.46	1.61	1.60
	F	0.89	0.63	0.94	0.82
	avg	1.30	1.04	1.28	1.21
Disk Chain	I	0.87	0.74	1.01	0.87
	F	0.52	1.20	0.65	0.79
	avg	0.70	0.97	0.83	0.83

* n=10/rep
** n=30/rep

Table AI.2 (A-AA). Cont.

K. Sampled December 3, 1990

Moisture (%)*

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	8.49	7.69	7.57	7.92
Amazon	I	8.65	7.16	3.79	6.53
	F	10.07	8.32	3.36	7.25
	avg	9.36	7.74	3.57	6.89
Disk Chain	I	7.10	6.31	6.54	6.65
	F	6.28	7.22	8.15	7.22
	avg	6.69	6.76	7.34	6.93
			Bulk Density (g/cm3)*		
Control	—	1.06	1.09	1.15	1.10
Amazon	I	0.99	1.15	1.39	1.18
	F	0.97	1.13	1.46	1.19
	avg	0.98	1.14	1.42	1.18
Disk Chain	I	1.20	1.19	1.13	1.17
	F	1.22	1.16	1.08	1.15
	avg	1.21	1.17	1.10	1.16
			Sheer Vane (kg/cm2)**		
Control	—	Frozen Soil - unable to sample			
Amazon	I				
	F				
	avg				
Disk Chain	I				
	F				
	avg				
			Penetrometer (kg/cm2)**		
Control	—	Frozen Soil - unable to sample			
Amazon	I				
	F				
	avg				
Disk Chain	I				
	F				
	avg				

* n=10/rep
** n=30/rep

Table AI.2 (A-AA). Cont.

L. Sampled January 4, 1991

Moisture (%)*

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	---	11.24	13.73	14.47	13.15
Amazon	I	10.33	8.37	9.07	9.26
	F	8.00	8.78	7.47	8.08
	avg	9.17	8.58	8.27	8.67
Disk Chain	I	8.38	9.66	12.65	10.23
	F	7.59	10.89	11.68	10.05
	avg	7.98	10.28	12.17	10.14

Bulk Density (g/cm3)*

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	---	1.16	1.01	0.93	1.03
Amazon	I	1.14	1.26	1.27	1.22
	F	1.17	1.15	1.34	1.22
	avg	1.15	1.20	1.31	1.22
Disk Chain	I	1.10	1.08	0.90	1.03
	F	1.16	1.00	0.90	1.02
	avg	1.13	1.04	0.90	1.02

Sheer Vane (kg/cm2)**

Treatment	Location	
Control	---	Frozen Soil - unable to sample
Amazon	I	
	F	
	avg	
Disk Chain	I	
	F	
	avg	

Penetrometer (kg/cm2)**

Treatment	Location	
Control	---	Frozen Soil - unable to sample
Amazon	I	
	F	
	avg	
Disk Chain	I	
	F	
	avg	

* n=10/rep
** n=30/rep

Table AI.2 (A-AA). Cont.

M. Sampled February 1, 1991

Moisture (%)*

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	35.80	14.53	19.36	23.23
Amazon	I	28.83	23.91	23.95	25.56
	F	23.02	21.89	23.72	22.88
	avg	25.92	22.90	23.83	24.22
Disk Chain	I	24.04	12.84	28.06	21.65
	F	29.06	19.72	27.03	25.27
	avg	26.55	16.28	27.55	23.46

Bulk Density (g/cm3)*

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	0.72	1.15	1.23	1.03
Amazon	I	0.95	1.05	1.08	1.03
	F	0.89	0.89	0.97	0.92
	avg	0.92	0.97	1.03	0.97
Disk Chain	I	0.94	1.19	1.11	1.08
	F	0.82	1.11	0.93	0.96
	avg	0.88	1.15	1.02	1.02

Sheer Vane (kg/cm2)**

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	Frozen Soil - unable to sample			
Amazon	I				
	F				
	avg				
Disk Chain	I				
	F				
	avg				

Penetrometer (kg/cm2)**

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	Frozen Soil - unable to sample			
Amazon	I				
	F				
	avg				
Disk Chain	I				
	F				
	avg				

* n=10/rep
** n=30/rep

Table AI.2 (A-AA). Cont.

N. Sampled March 5, 1991

Moisture (%)*

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	21.69	18.63	18.51	19.61
Amazon	I	23.33	19.15	16.18	19.56
	F	21.26	20.47	14.66	18.80
	avg	22.30	19.81	15.42	19.18
Disk Chain	I	21.62	19.59	22.36	21.19
	F	22.55	19.65	21.89	21.36
	avg	22.08	19.62	22.12	21.28

Bulk Density (g/cm3)*

Control	—	1.25	1.28	1.20	1.24
Amazon	I	1.09	1.11	1.16	1.12
	F	1.12	0.99	1.29	1.13
	avg	1.11	1.05	1.23	1.13
Disk Chain	I	0.94	0.97	0.81	0.91
	F	1.02	1.15	0.83	1.00
	avg	0.98	1.06	0.82	0.95

Sheer Vane (kg/cm2)**

Control	—	0.21	0.23	0.25	0.23
Amazon	I	0.16	0.12	0.13	0.14
	F	0.18	0.15	0.16	0.16
	avg	0.17	0.13	0.15	0.15
Disk Chain	I	0.08	0.17	0.07	0.10
	F	0.10	0.18	0.06	0.12
	avg	0.09	0.18	0.07	0.11

Penetrometer (kg/cm2)**

Control	—	0.17	0.18	0.45	0.27
Amazon	I	0.42	0.77	0.73	0.64
	F	0.29	0.46	1.17	0.64
	avg	0.35	0.61	0.95	0.64
Disk Chain	I	0.22	0.24	0.13	0.20
	F	0.28	0.34	0.16	0.26
	avg	0.25	0.29	0.15	0.23

* n=10/rep
** n=30/rep

Table AI.2 (A-AA). Cont.

O. Sampled March 29, 1991

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
			Moisture (%)*		
Control	—	6.50	5.69	11.79	7.99
Amazon	I	15.94	13.40	10.74	13.36
	F	15.52	13.53	13.84	14.29
	avg	15.73	13.47	12.29	13.83
Disk Chain	I	10.58	14.31	11.93	12.27
	F	11.36	12.27	13.11	12.25
	avg	10.97	13.29	12.52	12.26
			Bulk Density (g/cm3)*		
Control	—	1.16	1.28	0.99	1.15
Amazon	I	1.16	1.07	1.19	1.14
	F	1.05	0.95	1.01	1.00
	avg	1.11	1.01	1.10	1.07
Disk Chain	I	1.03	0.99	0.97	1.00
	F	1.01	0.97	0.91	0.96
	avg	1.02	0.98	0.94	0.98
			Sheer Vane (kg/cm2)**		
Control	—	0.15	0.17	0.08	0.13
Amazon	I	0.16	0.13	0.13	0.14
	F	0.18	0.19	0.19	0.19
	avg	0.17	0.16	0.16	0.16
Disk Chain	I	0.07	0.04	0.04	0.05
	F	0.12	0.06	0.05	0.08
	avg	0.10	0.05	0.04	0.06
			Penetrometer (kg/cm2)**		
Control	—	0.95	1.25	0.36	0.85
Amazon	I	1.47	0.77	1.23	1.15
	F	0.98	0.57	1.43	0.99
	avg	1.22	0.67	1.33	1.07
Disk Chain	I	0.33	0.23	0.24	0.27
	F	0.38	0.21	0.14	0.24
	avg	0.36	0.22	0.19	0.26

* n=10/rep

** n=30/rep

Table AI.2 (A-AA). Continued.

P. Sampled May 1, 1991

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
			Moisture (%)*		
Control	—	5.19	2.96	2.27	3.47
Amazon	I	5.32	4.17	3.93	4.47
	F	5.37	5.49	3.92	4.93
	avg	5.34	4.83	3.92	4.70
Disk Chain	I	4.83	5.50	4.31	4.88
	F	5.41	6.05	6.22	5.89
	avg	5.12	5.77	5.26	5.39
			Bulk Density (g/cm3)*		
Control	—	1.08	1.19	1.30	1.19
Amazon	I	0.98	1.12	1.21	1.10
	F	1.05	1.13	1.12	1.10
	avg	1.02	1.12	1.17	1.10
Disk Chain	I	1.08	1.13	1.05	1.09
	F	1.07	1.18	1.08	1.11
	avg	1.08	1.15	1.07	1.10
			Sheer Vane (kg/cm2)**		
Control	—	0.09	0.08	0.13	0.10
Amazon	I	0.11	0.10	0.10	0.10
	F	0.10	0.09	0.09	0.10
	avg	0.10	0.10	0.10	0.10
Disk Chain	I	0.05	0.12	0.10	0.09
	F	0.06	0.17	0.11	0.11
	avg	0.05	0.14	0.10	0.10
			Penetrometer (kg/cm2)**		
Control	—	0.35	0.43	0.89	0.56
Amazon	I	0.85	0.75	0.57	0.72
	F	0.45	0.40	0.48	0.44
	avg	0.65	0.57	0.52	0.58
Disk Chain	I	0.18	0.41	0.72	0.44
	F	0.26	1.58	0.46	0.77
	avg	0.22	0.99	0.59	0.60

* n=10/rep
** n=30/rep

Table AI.2 (A-AA). Cont.

Q. Sampled June 3, 1991

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
			Moisture (%)*		
Control	---	4.56	2.07	4.34	3.66
Amazon	I	5.04	5.38	2.89	4.44
	F	4.85	5.29	2.22	4.12
	avg	4.95	5.34	2.55	4.28
Disk Chain	I	3.63	3.56	3.45	3.55
	F	4.56	3.47	3.07	3.70
	avg	4.10	3.52	3.26	3.62
			Bulk Density (g/cm3)*		
Control	---	1.10	1.31	1.15	1.19
Amazon	I	1.05	1.03	1.36	1.15
	F	1.07	1.00	1.34	1.13
	avg	1.06	1.01	1.35	1.14
Disk Chain	I	1.10	1.20	1.10	1.13
	F	1.05	1.20	1.14	1.13
	avg	1.08	1.20	1.12	1.13
			Sheer Vane (kg/cm2)**		
Control	---	0.08	0.15	0.07	0.10
Amazon	I	0.12	0.10	0.09	0.10
	F	0.10	0.12	0.14	0.12
	avg	0.11	0.11	0.11	0.11
Disk Chain	I	0.07	0.06	0.10	0.07
	F	0.07	0.09	0.11	0.09
	avg	0.07	0.07	0.10	0.08
			Penetrometer (kg/cm2)**		
Control	---	0.32	0.78	0.34	0.48
Amazon	I	0.30	0.33	1.02	0.55
	F	0.22	0.40	0.97	0.53
	avg	0.26	0.36	0.99	0.54
Disk Chain	I	0.27	0.14	0.27	0.23
	F	0.32	0.34	0.56	0.40
	avg	0.29	0.24	0.41	0.32

* n=10/rep
** n=30/rep

Table AI.2 (A-AA). Cont.

R. Sampled August 1, 1991

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
			Moisture (%)*		
Control	---	1.08	1.78	1.46	1.44
Amazon	I	1.49	1.24	1.05	1.26
	F	1.34	1.42	0.95	1.24
	avg	1.41	1.33	1.00	1.25
Disk Chain	I	2.01	1.75	2.05	1.93
	F	2.00	1.77	2.47	2.08
	avg	2.00	1.76	2.26	2.01
			Bulk Density (g/cm3)*		
Control	---	1.25	1.23	1.31	1.26
Amazon	I	1.22	1.37	1.35	1.31
	F	1.29	1.28	1.41	1.33
	avg	1.26	1.32	1.38	1.32
Disk Chain	I	1.15	1.33	1.05	1.18
	F	1.21	1.29	1.04	1.18
	avg	1.18	1.31	1.05	1.18
			Sheer Vane (kg/cm2)**		
Control	---	0.09	0.09	0.09	0.09
Amazon	I	0.11	0.08	0.09	0.09
	F	0.10	0.12	0.11	0.11
	avg	0.10	0.10	0.10	0.10
Disk Chain	I	0.05	0.08	0.05	0.06
	F	0.06	0.07	0.06	0.06
	avg	0.06	0.08	0.05	0.06
			Penetrometer (kg/cm2)**		
Control	---	0.45	0.32	0.69	0.49
Amazon	I	0.35	0.66	0.93	0.65
	F	0.38	0.65	0.82	0.62
	avg	0.37	0.66	0.87	0.63
Disk Chain	I	0.17	0.25	0.10	0.17
	F	0.32	1.04	0.11	0.49
	avg	0.25	0.64	0.10	0.33

* n=10/rep
** n=30/rep

Table AI.2 (A-AA). Cont.

S. Sampled October 1, 1991

Moisture (%)

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	2.57	2.39	2.13	2.36
Amazon	I	2.40	2.12	2.32	2.28
	F	2.46	2.15	2.53	2.38
	avg	2.43	2.14	2.42	2.33
Disk Chain	I	2.40	1.44	2.72	2.19
	F	2.42	1.48	2.72	2.21
	avg	2.41	1.46	2.72	2.20

Bulk Density (g/cm3)

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	1.31	1.33	1.40	1.34
Amazon	I	1.31	1.33	1.17	1.27
	F	1.23	1.24	1.23	1.23
	avg	1.27	1.28	1.20	1.25
Disk Chain	I	1.18	1.26	1.14	1.19
	F	1.18	1.30	1.11	1.20
	avg	1.18	1.28	1.13	1.20

Sheer Vane (kg/cm2)

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	0.05	0.05	0.07	0.06
Amazon	I	0.09	0.08	0.10	0.09
	F	0.10	0.10	0.11	0.10
	avg	0.10	0.09	0.11	0.10
Disk Chain	I	0.08	0.14	0.05	0.09
	F	0.08	0.11	0.06	0.08
	avg	0.08	0.12	0.06	0.09

Penetrometer (kg/cm2)

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	0.80	0.76	0.84	0.80
Amazon	I	0.74	0.72	0.74	0.74
	F	0.48	0.70	0.81	0.66
	avg	0.61	0.71	0.77	0.70
Disk Chain	I	0.44	1.27	0.36	0.69
	F	0.48	0.93	0.27	0.56
	avg	0.46	1.10	0.32	0.63

Table AI.2 (A-AA). Cont.

T. Sampled November 5, 1991

Moisture (%)

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	13.68	13.05	17.66	14.80
Amazon	I	15.49	15.72	14.81	15.34
	F	14.83	15.88	14.30	15.01
	avg	15.16	15.80	14.56	15.17
Disk Chain	I	14.31	16.33	19.82	16.82
	F	13.72	16.80	20.84	17.12
	avg	14.01	16.56	20.33	16.97

Bulk Density (g/cm3)

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	1.30	1.23	1.19	1.24
Amazon	I	1.19	1.00	1.07	1.09
	F	1.12	0.93	1.18	1.08
	avg	1.16	0.97	1.12	1.08
Disk Chain	I	1.08	1.06	0.95	1.03
	F	1.07	1.08	0.94	1.03
	avg	1.08	1.07	0.95	1.03

Sheer Vane (kg/cm2)

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	0.09	0.08	0.08	0.09
Amazon	I	0.13	0.17	0.17	0.16
	F	0.19	0.18	0.20	0.19
	avg	0.16	0.18	0.19	0.17
Disk Chain	I	0.08	0.07	0.07	0.07
	F	0.09	0.08	0.07	0.08
	avg	0.08	0.08	0.07	0.08

Penetrometer (kg/cm2)

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	0.85	0.44	0.27	0.52
Amazon	I	1.24	0.84	0.82	0.97
	F	1.16	0.64	0.74	0.85
	avg	1.20	0.74	0.78	0.91
Disk Chain	I	0.55	0.21	0.17	0.31
	F	0.48	0.24	0.17	0.29
	avg	0.51	0.22	0.17	0.30

Table AI.2 (A-AA). Cont.

U. Sampled December 6, 1991

Moisture (%)

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	---	24.54	23.91	23.62	24.02
Amazon	I	23.31	21.51	22.35	22.39
	F	24.00	22.34	22.72	23.02
	avg	23.65	21.93	22.54	22.71
Disk Chain	I	20.07	18.93	22.78	20.59
	F	20.86	22.48	23.41	22.25
	avg	20.46	20.71	23.10	21.42

Bulk Density (g/cm3)

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	---	1.35	1.24	1.16	1.25
Amazon	I	0.98	1.17	1.17	1.11
	F	0.98	1.00	1.07	1.02
	avg	0.98	1.08	1.12	1.06
Disk Chain	I	1.01	1.32	1.23	1.19
	F	1.06	1.13	1.19	1.13
	avg	1.03	1.23	1.21	1.16

Sheer Vane (kg/cm2)

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	---	0.08	0.07	0.08	0.07
Amazon	I	0.14	0.17	0.11	0.14
	F	0.16	0.18	0.12	0.15
	avg	0.15	0.17	0.11	0.15
Disk Chain	I	0.05	0.08	0.27	0.13
	F	0.06	0.08	0.09	0.08
	avg	0.05	0.08	0.18	0.10

Penetrometer (kg/cm2)

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	---	0.25	0.26	0.19	0.23
Amazon	I	0.34	0.44	0.28	0.35
	F	0.36	0.42	0.24	0.34
	avg	0.35	0.43	0.26	0.35
Disk Chai	I	0.12	0.38	0.26	0.25
	F	0.16	0.31	0.26	0.24
	avg	0.14	0.34	0.26	0.25

Table AI.2 (A-AA). Cont.

V. Sampled January 2, 1992

Treatment	Location	Moisture (%) Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	23.18	13.55	21.17	19.30
Amazon	I	22.64	26.41	17.07	22.04
	F	23.86	31.03	21.68	25.52
	avg	23.25	28.72	19.37	23.78
Disk Chain	I	16.19	13.49	15.16	14.95
	F	19.72	14.41	14.03	16.05
	avg	17.96	13.95	14.60	15.50

Bulk Density (g/cm3)

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	1.07	1.20	1.15	1.14
Amazon	I	0.99	0.96	1.11	1.02
	F	0.80	0.88	1.05	0.91
	avg	0.90	0.92	1.08	0.96
Disk Chain	I	0.89	1.03	0.92	0.95
	F	0.91	1.00	0.86	0.93
	avg	0.90	1.02	0.89	0.94

Sheer Vane (kg/cm2)

Treatment	Location	
Control	—	
Amazon	I	
	F	Frozen Soil -- Unable to Sample
	avg	
Disk Chain	I	
	F	
	avg	

Penetrometer (kg/cm2)

Treatment	Location	
Control	—	
Amazon	I	
	F	Frozen Soil -- Unable to Sample
	avg	
Disk Chain	I	
	F	
	avg	

Table AI.2 (A-AA). Cont.

W. Sampled February 1, 1992

Moisture (%)

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	---	18.49	14.25	17.99	16.91
Amazon	I	26.00	21.64	14.93	20.85
	F	22.30	23.46	14.82	20.19
	avg	24.15	22.55	14.88	20.52
Disk Chain	I	19.05	10.69	18.46	16.07
	F	20.67	11.37	18.83	16.96
	avg	19.86	11.03	18.65	16.51

Bulk Density (g/cm3)

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	---	1.08	1.15	1.06	1.10
Amazon	I	1.03	0.91	1.25	1.06
	F	0.96	0.73	1.12	0.94
	avg	0.99	0.82	1.19	1.00
Disk Chain	I	1.02	1.05	0.97	1.01
	F	1.05	1.14	0.91	1.03
	avg	1.03	1.09	0.94	1.02

Sheer Vane (kg/cm2)

Treatment	Location	
Control	---	
Amazon	I	
	F	Frozen Soil -- Unable to Sample
	avg	
Disk Chain	I	
	F	
	avg	

Penetrometer (kg/cm2)

Treatment	Location	
Control	---	
Amazon	I	
	F	Frozen Soil -- Unable to Sample
	avg	
Disk Chain	I	
	F	
	avg	

Table AI.2 (A-AA). Cont.

X. Sampled March 5, 1992

Moisture (%)

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	16.43	12.26	10.84	13.18
Amazon	I	20.57	16.86	10.89	16.11
	F	22.45	16.71	14.78	17.98
	avg	21.51	16.79	12.84	17.05
Disk Chain	I	14.83	7.28	13.81	11.97
	F	15.39	6.80	15.00	12.40
	avg	15.11	7.04	14.41	12.18
		Bulk Density (g/cm3)			
Control	—	1.15	1.15	1.26	1.19
Amazon	I	1.19	1.06	1.07	1.11
	F	0.97	1.01	0.98	0.99
	avg	1.08	1.04	1.03	1.05
Disk Chain	I	0.92	1.22	0.91	1.01
	F	1.14	1.18	0.90	1.07
	avg	1.03	1.20	0.90	1.04
		Sheer Vane (kg/cm2)			
Control	—	0.39	0.24	0.49	0.37
Amazon	I	0.24	0.18	0.14	0.18
	F	0.25	0.20	0.16	0.20
	avg	0.24	0.19	0.15	0.19
Disk Chain	I	0.07	0.12	0.12	0.10
	F	0.07	0.06	0.15	0.09
	avg	0.07	0.09	0.13	0.10
		Penetrometer (kg/cm2)			
Control	—	0.21	0.35	0.61	0.39
Amazon	I	0.65	0.68	0.69	0.68
	F	0.70	0.64	0.53	0.62
	avg	0.68	0.66	0.61	0.65
Disk Chain	I	1.31	0.55	0.21	0.69
	F	1.08	0.44	0.27	0.60
	avg	1.20	0.50	0.24	0.65

Table AI.2 (A-AA). Cont.

Y. Sampled April 2, 1992

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
		Moisture (%)			
Control	---	4.78	3.28	4.31	4.12
Amazon	I	8.30	2.86	2.61	4.59
	F	8.34	3.95	2.88	5.06
	avg	8.32	3.41	2.75	4.83
Disk Chain	I	5.44	5.26	8.87	6.52
	F	6.27	6.80	6.05	6.38
	avg	5.86	6.03	7.46	6.45
		Bulk Density (g/cm3)			
Control	---	1.24	1.25	1.28	1.25
Amazon	I	0.97	1.20	1.20	1.12
	F	1.03	1.14	1.27	1.15
	avg	1.00	1.17	1.24	1.14
Disk Chain	I	1.00	1.18	1.00	1.06
	F	1.05	1.06	0.92	1.01
	avg	1.02	1.12	0.96	1.03
		Sheer Vane (kg/cm2)			
Control	---	0.09	0.06	0.06	0.07
Amazon	I	0.18	0.12	0.11	0.14
	F	0.20	0.18	0.16	0.18
	avg	0.19	0.15	0.13	0.16
Disk Chain	I	0.03	0.10	0.06	0.07
	F	0.04	0.10	0.06	0.07
	avg	0.04	0.10	0.06	0.07
		Penetrometer (kg/cm2)			
Control	---	0.82	0.64	0.63	0.69
Amazon	I	0.87	0.42	1.52	0.94
	F	0.85	0.67	1.38	0.97
	avg	0.86	0.55	1.45	0.95
Disk Chain	I	0.17	1.95	0.19	0.77
	F	0.25	1.74	0.23	0.74
	avg	0.21	1.84	0.21	0.75

Table AI.2 (A-AA). Cont.

Z. Sampled May 8, 1992

Moisture (%)

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
Control	—	1.69	2.33	4.32	2.78
Amazon	I	2.82	2.78	2.78	2.79
	F	3.23	2.75	3.25	3.08
	avg	3.02	2.76	3.02	2.94
Disk Chain	I	3.58	2.02	3.31	2.97
	F	3.74	2.43	3.25	3.14
	avg	3.66	2.22	3.28	3.06
		Bulk Density (g/cm3)			
Control	—	1.39	1.37	1.13	1.30
Amazon	I	1.02	1.06	1.10	1.06
	F	1.07	1.18	1.08	1.11
	avg	1.05	1.12	1.09	1.09
Disk Chain	I	1.02	1.23	1.11	1.12
	F	1.05	1.22	1.03	1.10
	avg	1.04	1.23	1.07	1.11
		Sheer Vane (kg/cm2)			
Control	—	0.08	0.09	0.06	0.08
Amazon	I	0.09	0.17	0.11	0.13
	F	0.12	0.15	0.13	0.13
	avg	0.11	0.16	0.12	0.13
Disk Chain	I	0.05	0.06	0.04	0.05
	F	0.05	0.07	0.04	0.05
	avg	0.05	0.06	0.04	0.05
		Penetrometer (kg/cm2)			
Control	—	0.94	0.94	0.31	0.73
Amazon	I	0.50	0.81	0.82	0.71
	F	0.70	0.63	1.03	0.79
	avg	0.60	0.72	0.93	0.75
Disk Chain	I	0.18	1.38	0.22	0.59
	F	0.18	2.04	0.22	0.81
	avg	0.18	1.71	0.22	0.70

Table AI.2 (A-AA). Cont.

AA. Sampled June 2, 1992

Treatment	Location	Rep 1	Rep 2	Rep 3	Average of Reps
		Moisture (%)			
Control	---	1.71	1.48	1.55	1.58
Amazon	I	1.54	1.46	1.80	1.60
	F	1.70	1.62	1.80	1.71
	avg	1.62	1.54	1.80	1.65
Disk Chain	I	2.21	1.72	2.05	1.99
	F	2.35	1.54	2.19	2.03
	avg	2.28	1.63	2.12	2.01
		Bulk Density (g/cm3)			
Control	---	1.25	1.21	1.24	1.24
Amazon	I	1.19	1.13	1.18	1.17
	F	1.12	0.98	1.09	1.06
	avg	1.15	1.05	1.14	1.11
Disk Chain	I	1.05	1.14	1.10	1.10
	F	1.04	1.24	1.03	1.11
	avg	1.05	1.19	1.07	1.10
		Sheer Vane (kg/cm2)			
Control	---	0.19	0.19	0.16	0.18
Amazon	I	0.09	0.10	0.07	0.08
	F	0.09	0.10	0.09	0.09
	avg	0.09	0.10	0.08	0.09
Disk Chain	I	0.05	0.19	0.10	0.11
	F	0.09	0.20	0.14	0.14
	avg	0.07	0.19	0.12	0.13
		Penetrometer (kg/cm2)			
Control	---	0.73	0.42	0.53	0.56
Amazon	I	0.44	0.62	0.55	0.54
	F	0.47	0.68	0.46	0.54
	avg	0.46	0.65	0.50	0.54
Disk Chain	I	0.25	0.67	0.18	0.37
	F	0.40	0.93	0.22	0.52
	avg	0.33	0.80	0.20	0.44

Table AI.3. Post-treatment Mean Surface Roughness (cm)* by Treatment of Permanent Transects. Lockman Study Site, Mountain Home, Idaho.

	Treatment		
	Control	Amazon	Disk Chain
November 1989	1.07	1.96	2.08
June 1990	1.09	1.74	1.97
June 1991	1.16	1.94	1.94
June 1992	1.34	1.79	1.77

---

* Mean surface roughness is the pooled standard deviation of 8 permanent transects for each treatment. Each treatment is replicated 3 times.

Table AI.4. Post-treatment Mean* Ground Surface Condition (%) by Treatment of Permanent Transects. Sampled 1989-1991. Lockman Study Site, Mountain Home, Idaho.

	Treatment		
	Control	Amazon	Disk Chain
November 1989			
Grasses			
Agropyron cristatum	0.0	0.0	0.0
Bromus tectorum tectorum	0.4	0.1	0.0
Poa secunda	0.4	1.0	0.1
Sitanion hystrix hystrix	0.0	0.0	0.0
Forbs	0.0	0.0	0.0
Shrubs	0.0	0.0	0.0
Cryptograms	0.2	0.0	0.0
Litter	60.4	23.5	2.0
Rock	0.7	0.0	0.0
Bare Ground	37.9	75.4	97.9
June 1990			
Grasses			
Agropyron cristatum	0.0	1.4	1.4
Bromus tectorum tectorum	42.2	49.0	21.8
Poa secunda	2.1	3.7	0.4
Sitanion hystrix hystrix	0.1	0.5	23.6
Forbs	7.1	3.2	12.7
Shrubs	0.0	0.0	0.0
Cryptograms	2.3	0.0	0.0
Litter	16.0	6.8	0.8
Rock	0.8	0.3	0.6
Bare Ground	29.4	35.1	62.3
June 1991			
Grasses			
Agropyron cristatum	0.0	0.8	1.9
Bromus tectorum tectorum	45.4	47.4	33.5
Poa secunda	2.6	4.7	0.4
Sitanion hystrix hystrix	0.4	0.8	0.0
Forbs	4.9	4.4	11.8
Shrubs	0.0	0.0	0.0
Cryptograms	0.3	0.0	0.0
Litter	24.1	21.1	6.8
Rock	0.9	0.3	0.6
Bare Ground	21.4	20.5	45.0

Table AI.4 Cont.

	Control	Amazon	Disk Chain
June 1992			
Grasses			
Agropyron cristatum	0.0	0.0	0.0
Bromus tectorum tectorum	0.0	0.0	0.0
Poa secunda	0.0	0.0	0.0
Sitanion hystrix hystrix	0.0	0.0	0.0
Forbs	1.5	0.2	0.0
Shrubs	0.0	0.0	0.0
Cryptograms	0.0	0.0	0.0
Litter	85.3	81.0	59.2
Rock	1.5	1.3	2.8
Bare Ground	11.7	17.4	37.9

* Mean is for 8 permanent transects within each treatment replicated 3 times, n=1440.

Table AI.5. Organic Carbon by Replication (Rep) of Rainfall Simulation plots. Lockman Study Site, Mountain Home, Idaho.

Sample Date	Treatment	Organic Carbon (%) Rep 1	Rep 2	Rep 3	Average of Reps
June/ July 1990*	Control	1.11	1.30	1.41	1.29
	Amazon	2.18	1.18	1.48	1.62
	Disk Chain	1.15	0.97	0.91	1.01
June 1991**	Control	1.61	1.24	1.59	1.48
	Amazon	1.48	1.40	1.26	1.38
	Disk Chain	1.02	1.27	1.56	1.28
June 1992**	Control	0.66	0.87	0.74	0.75
	Amazon	0.81	1.07	1.00	0.96
	Disk Chain	0.89	1.39	1.06	1.11

* n=4/rep

** n=2/rep (each a composite of 4 samples/rep)

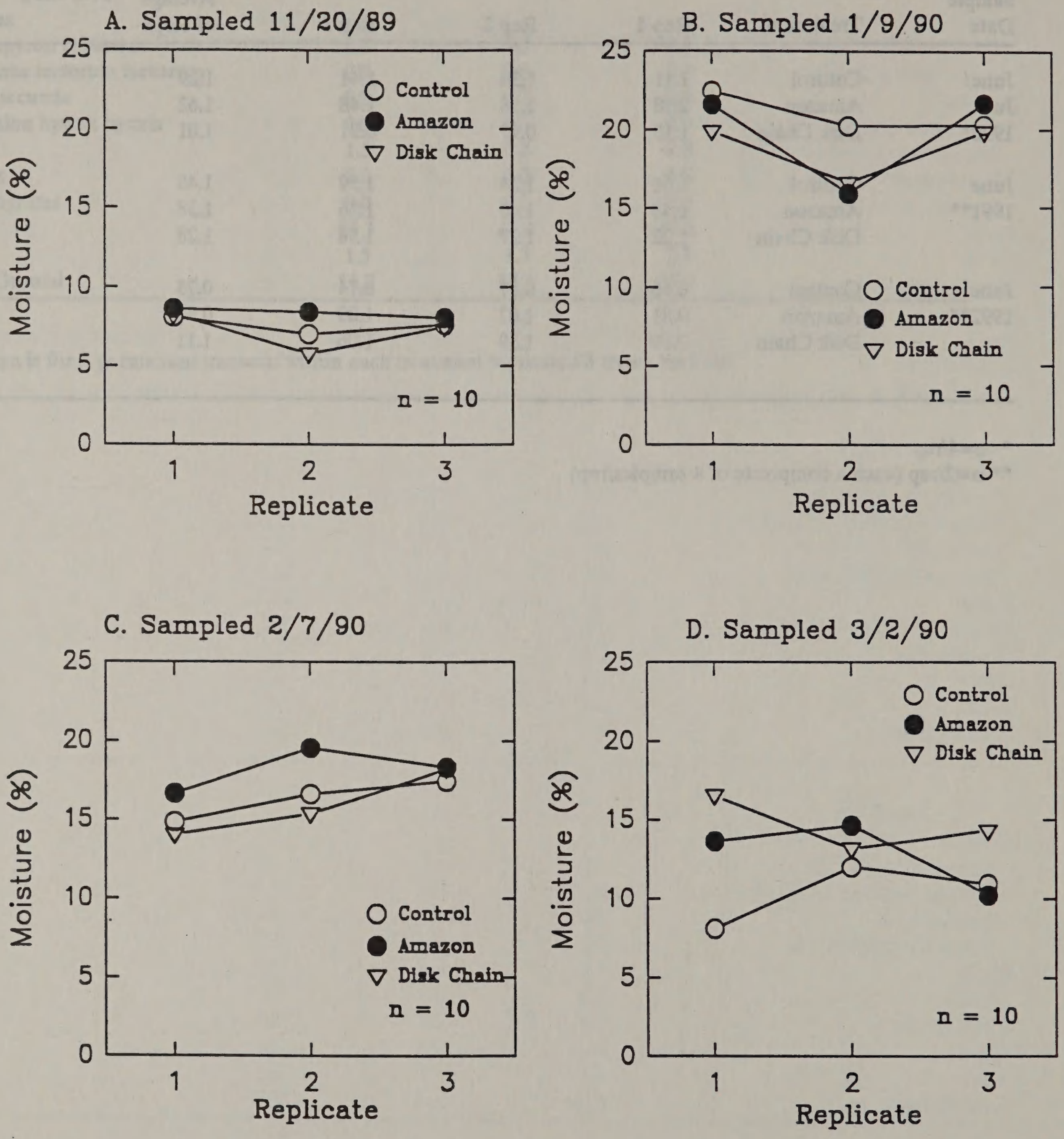
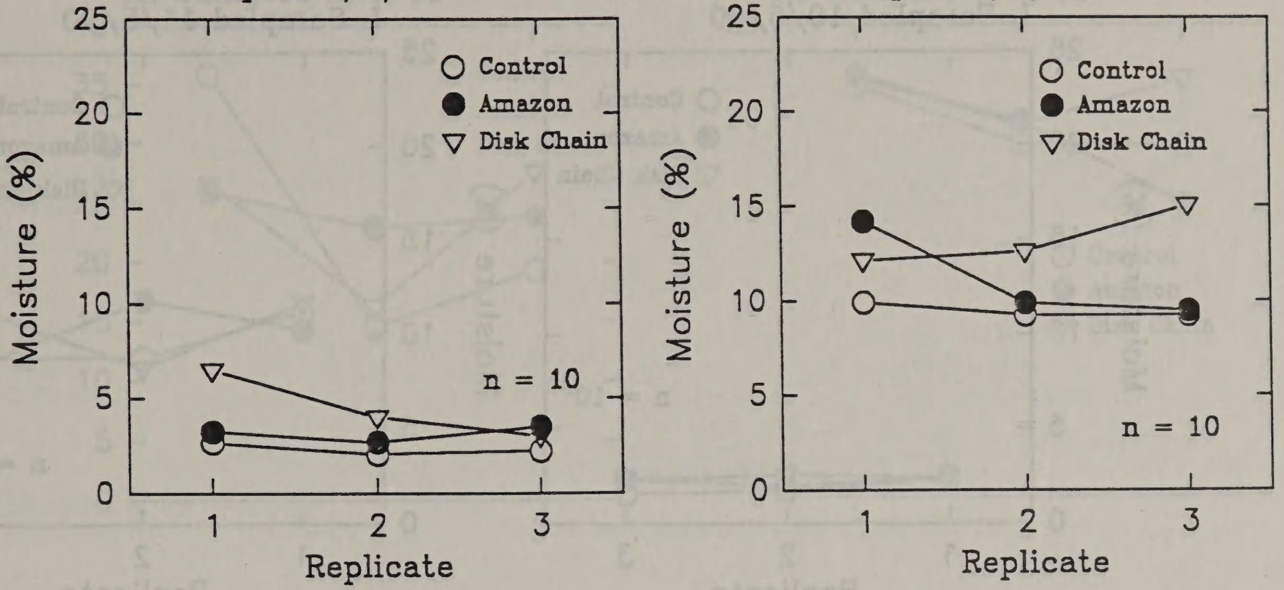
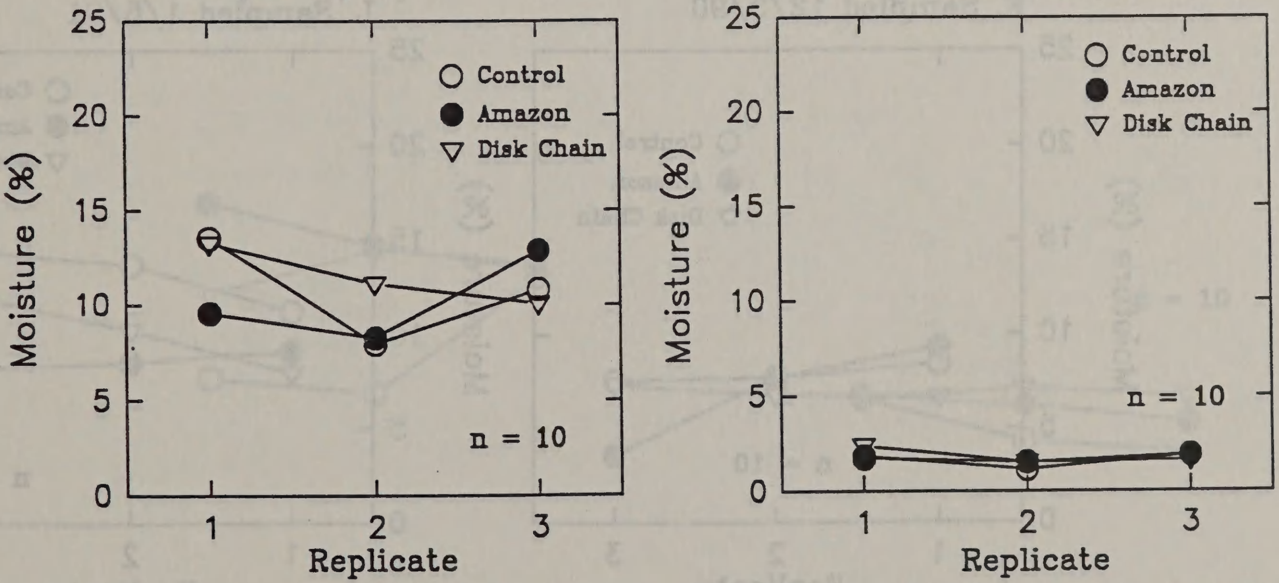


Figure AI.1 (A-AA) Moisture replicates for each sampling data (1989-1992). Greenstripping permanent transects.


E. Sampled 4/5/89

F. Sampled 5/2/90


G. Sampled 6/4/90

H. Sampled 8/1/90

Figure AI.1 (A-AA) Continued

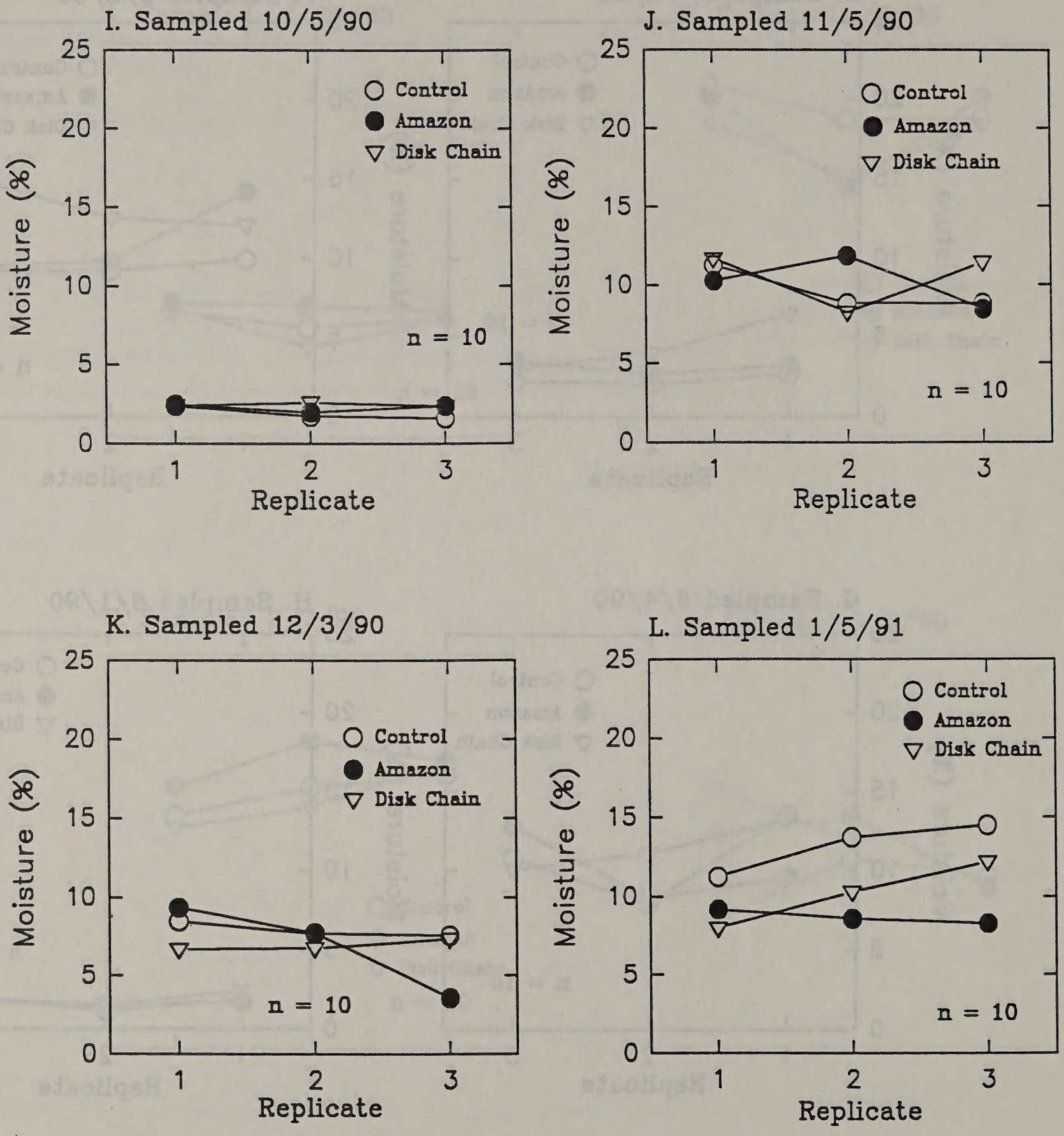
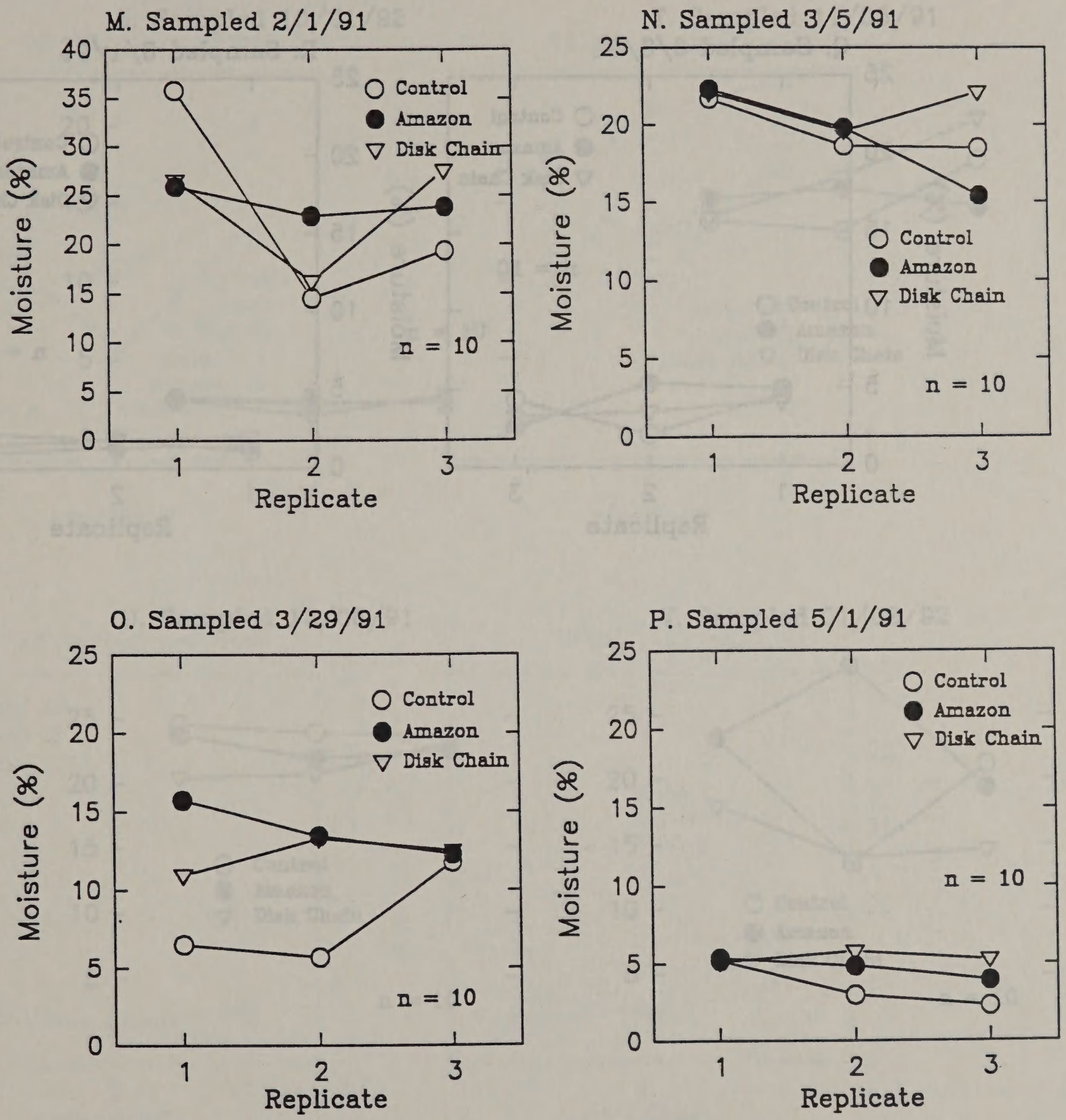


Figure AI.1 (A-AA) Continued



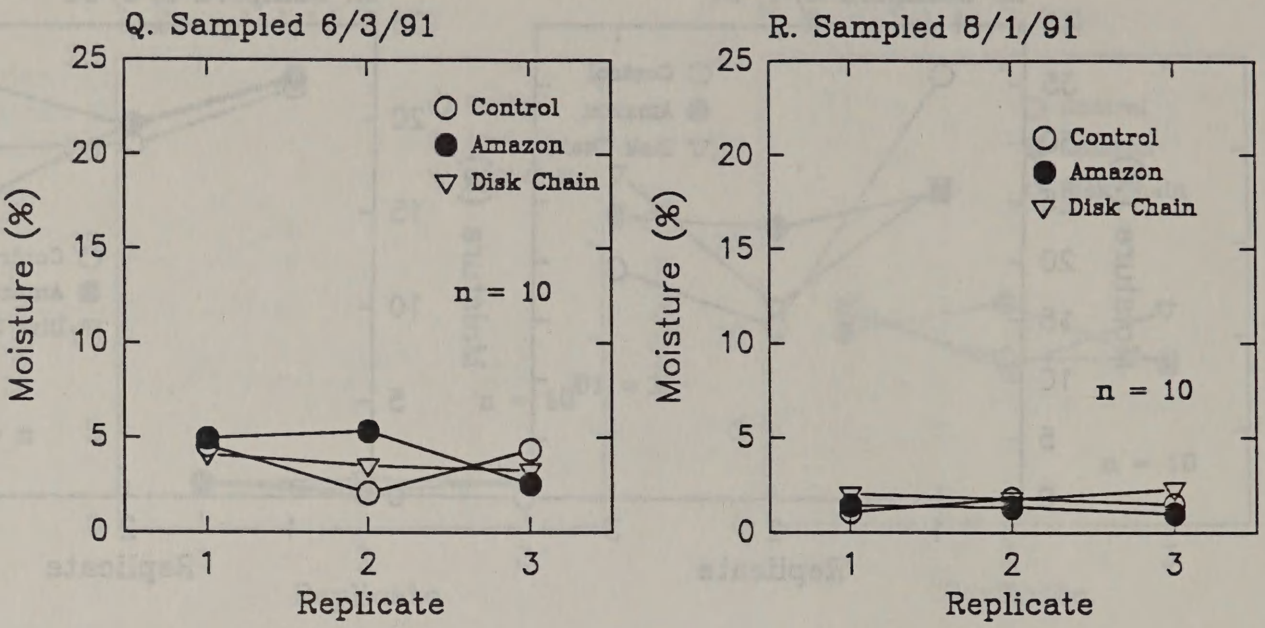
M. Sampled 2/1/91

N. Sampled 3/5/91

O. Sampled 3/29/91

P. Sampled 5/1/91

Figure AI.1 (A-AA) Continued


Q. Sampled 6/3/91

R. Sampled 8/1/91

Figure AI.1 (A-AA) Continued

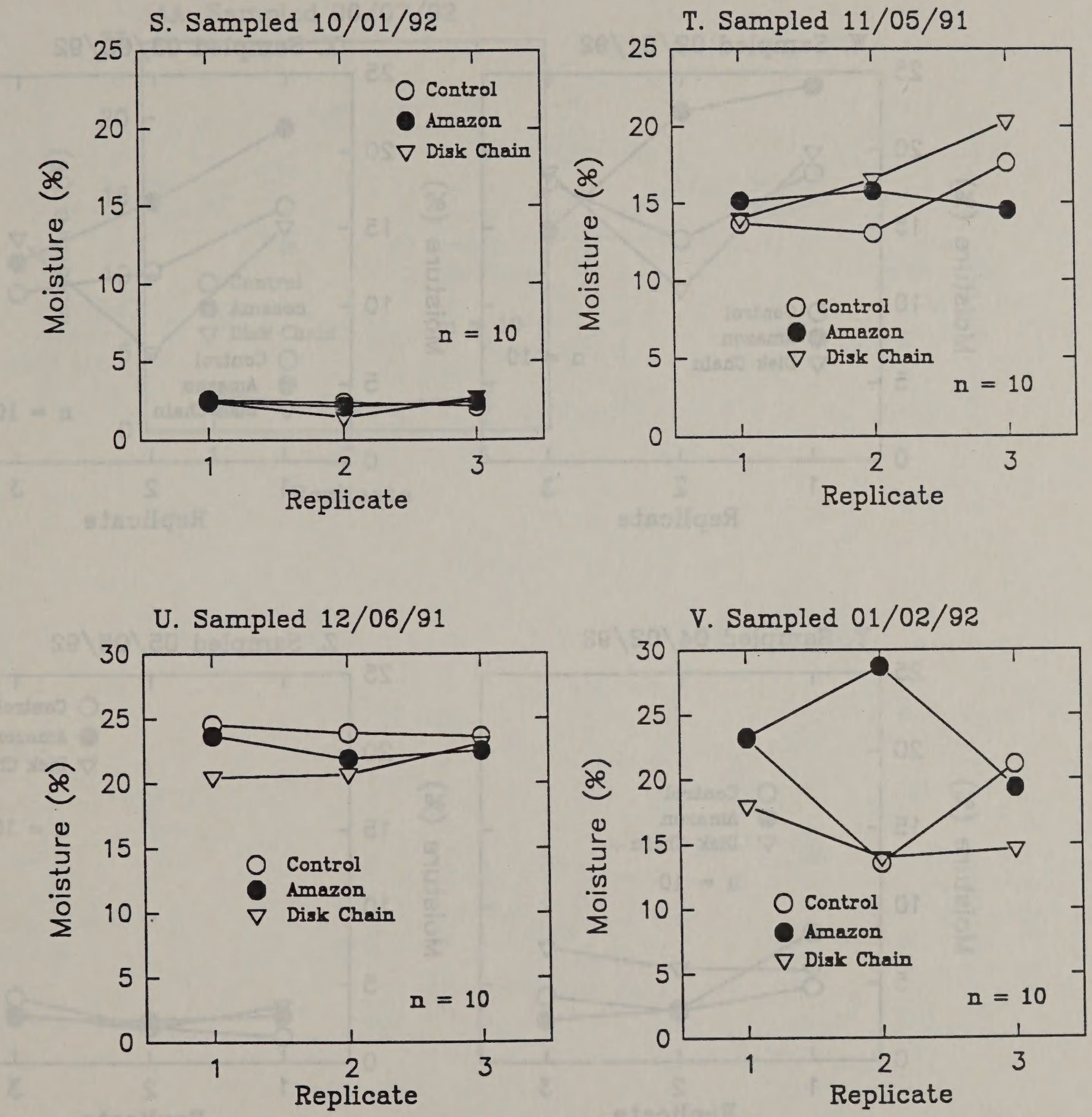


Figure AI.1 (A-AA) Continued

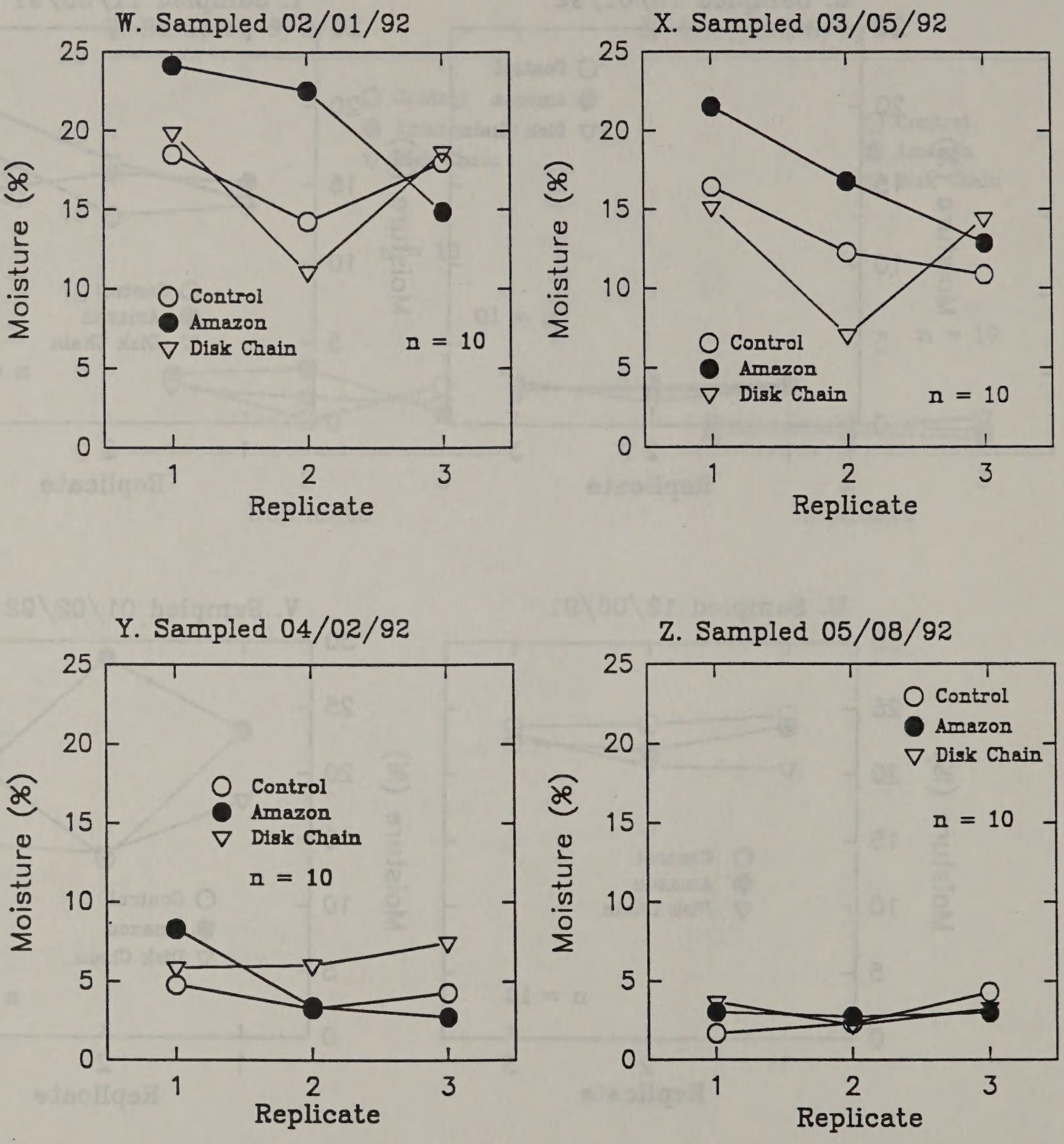


Figure AI.1 (A-AA) Continued

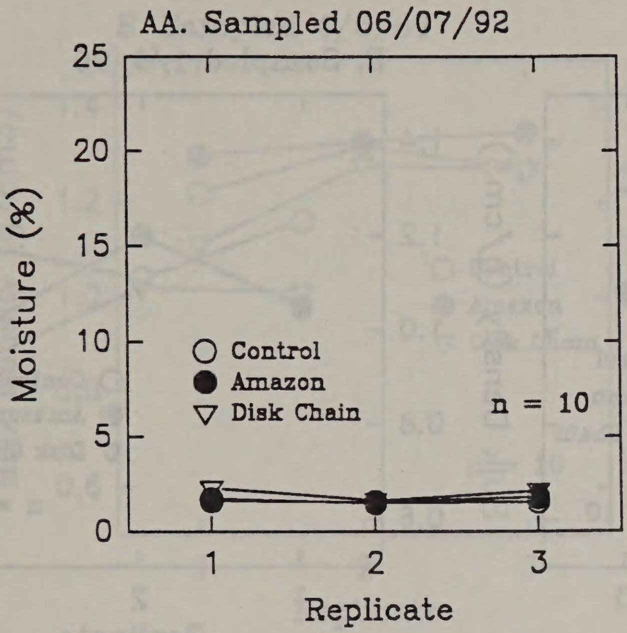


Figure AI.1 (A-AA) Continued

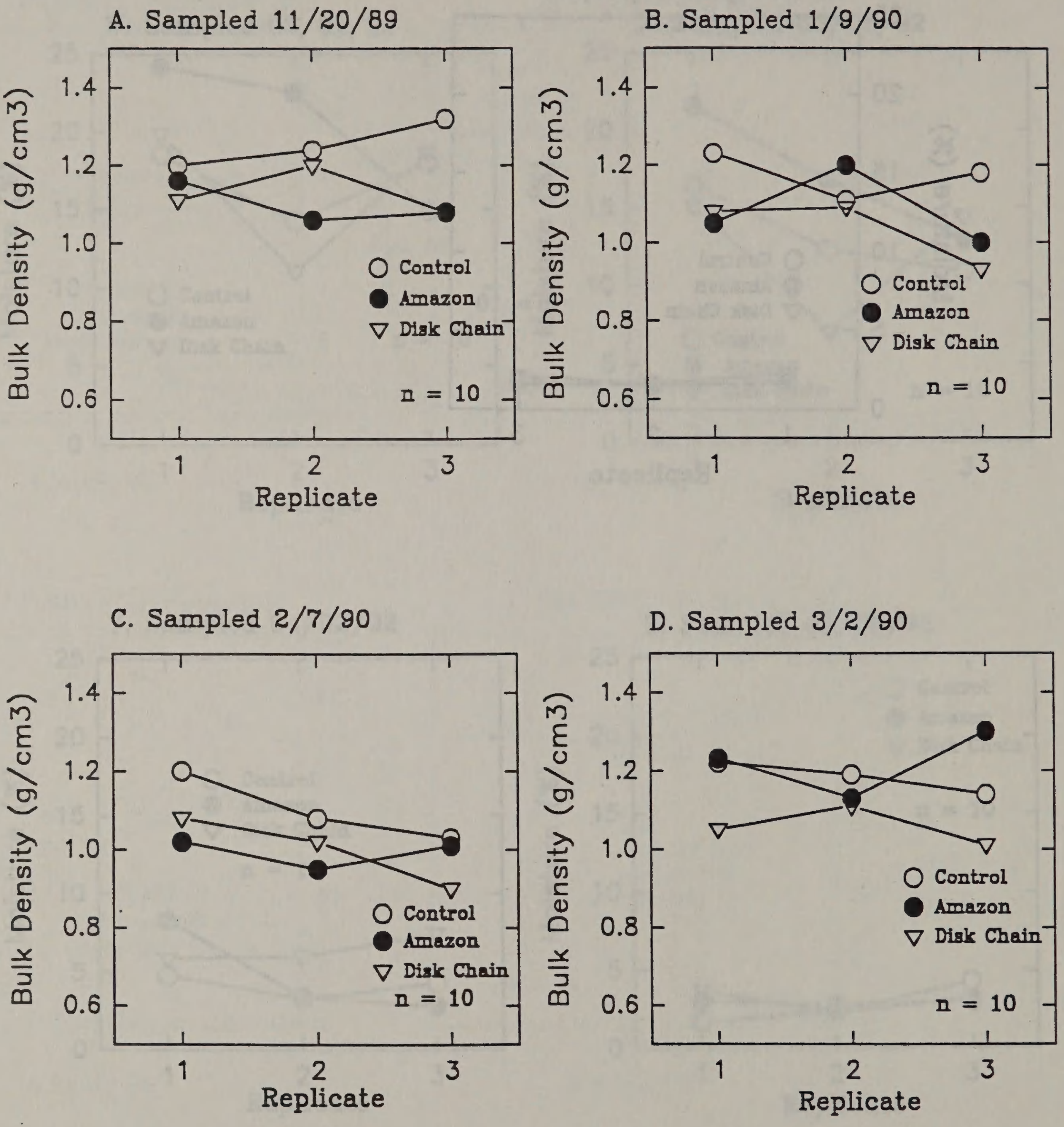


Figure AI.2 (A-AA) Bulk density replicates for each sampling date (1989-1992). Greenstripping, permanent transects.

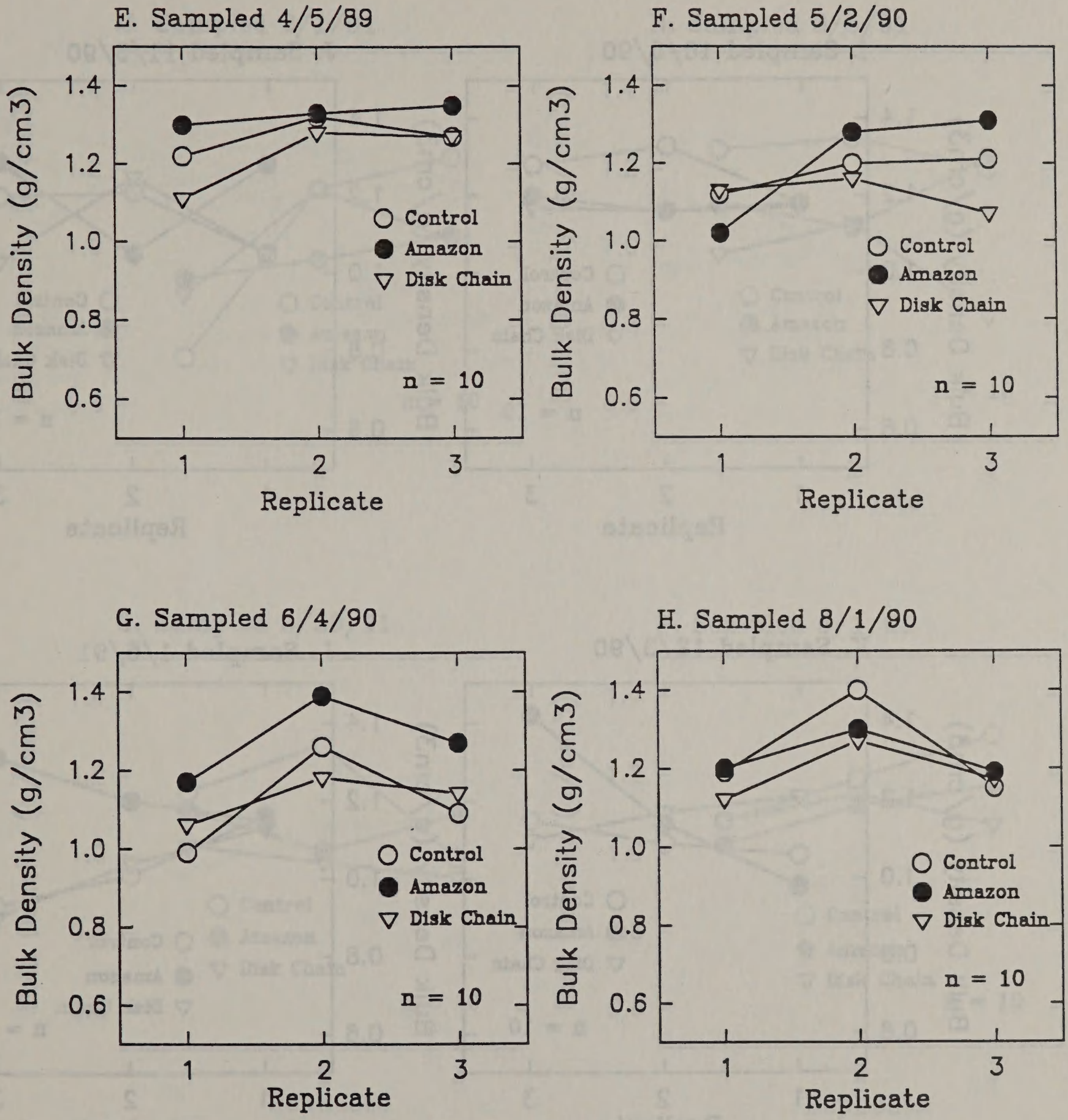
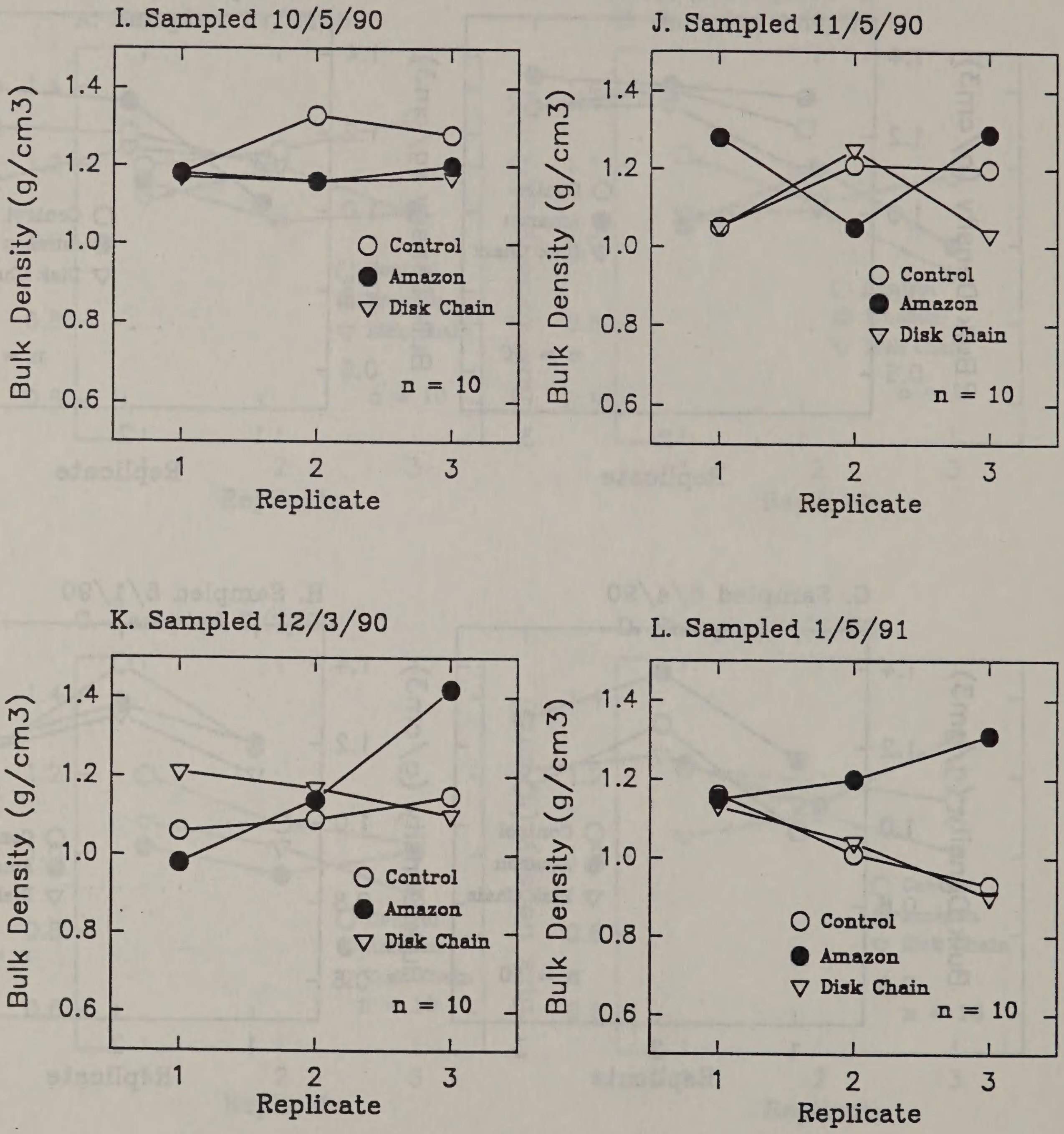


Figure AI.2 (A-AA) Continued



I. Sampled 10/5/90

J. Sampled 11/5/90

K. Sampled 12/3/90

L. Sampled 1/5/91

Figure AI.2 (A-AA) Continued

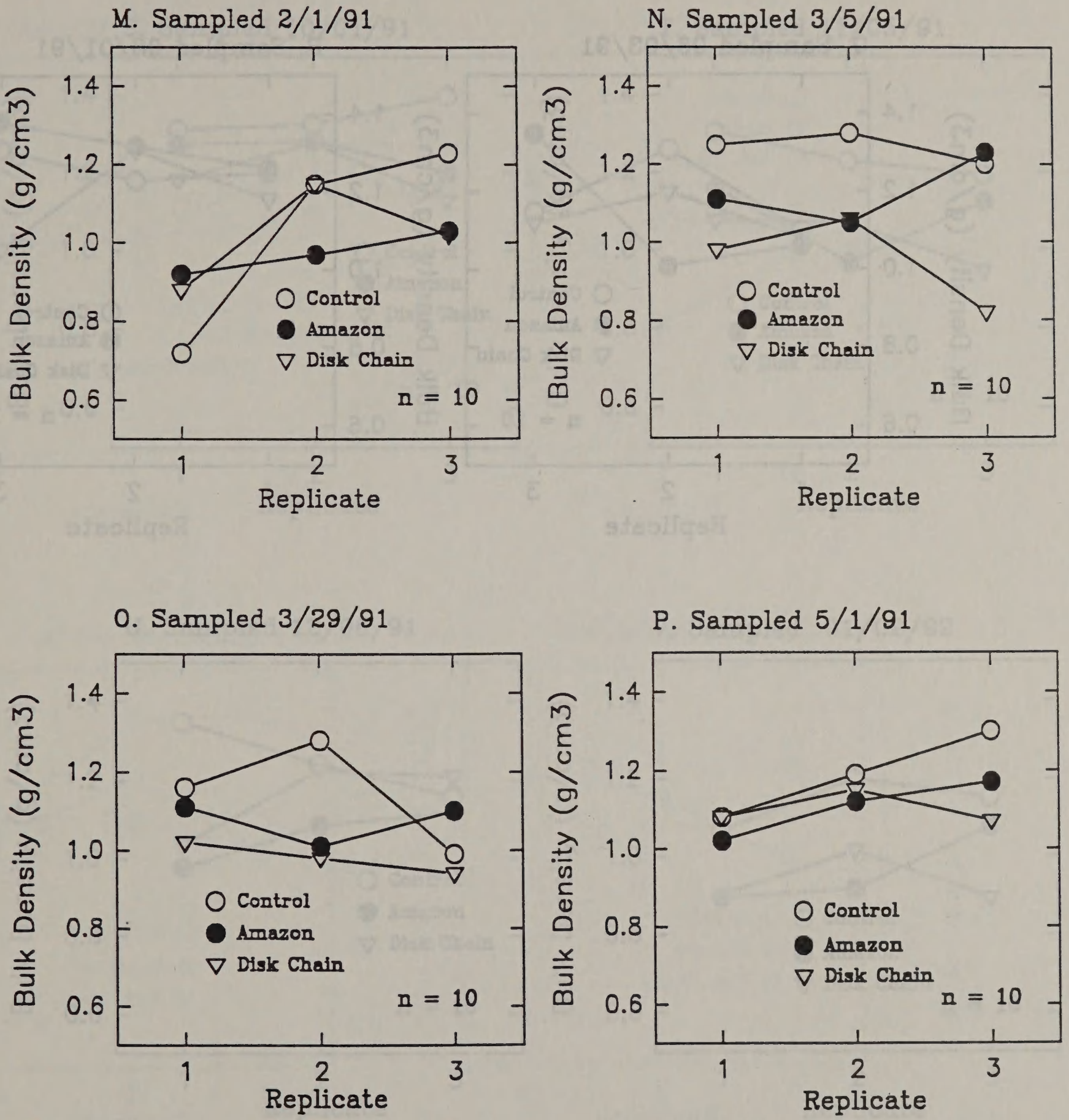
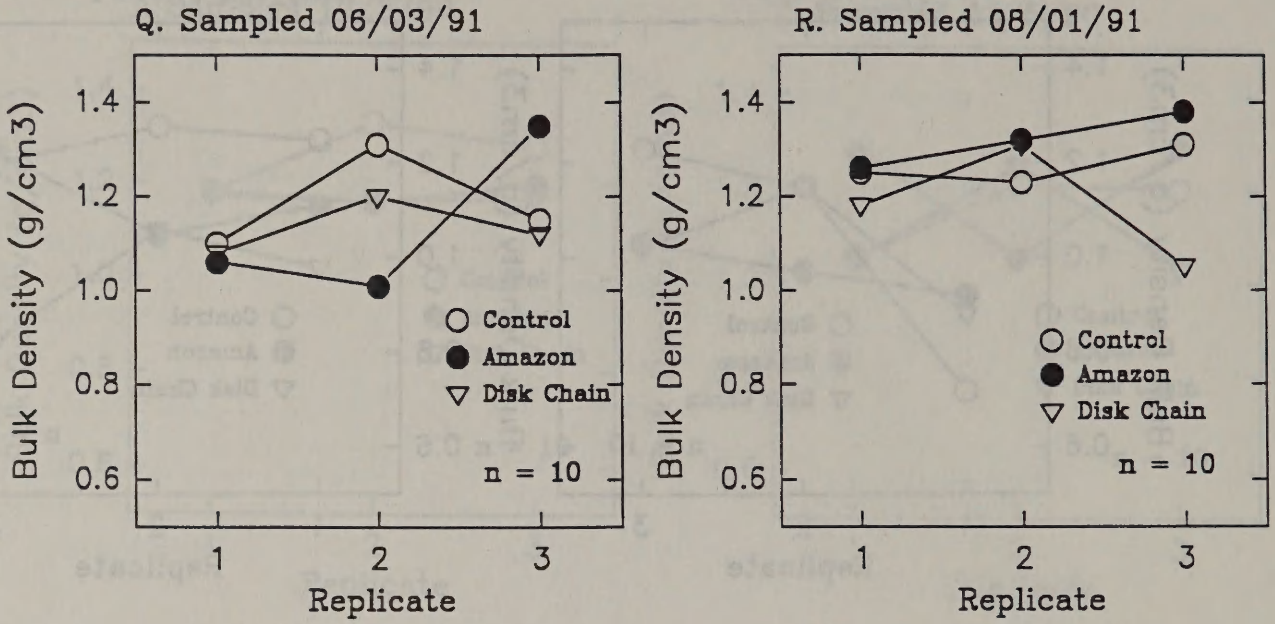


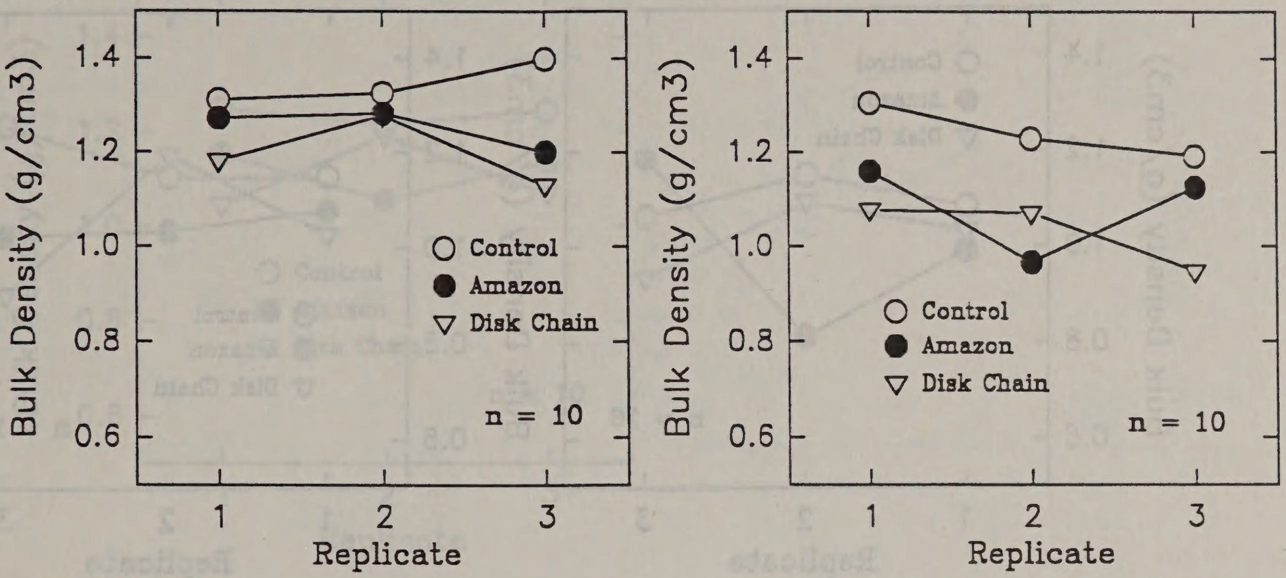
Figure AI.2 (A-AA) Continued



Q. Sampled 06/03/91

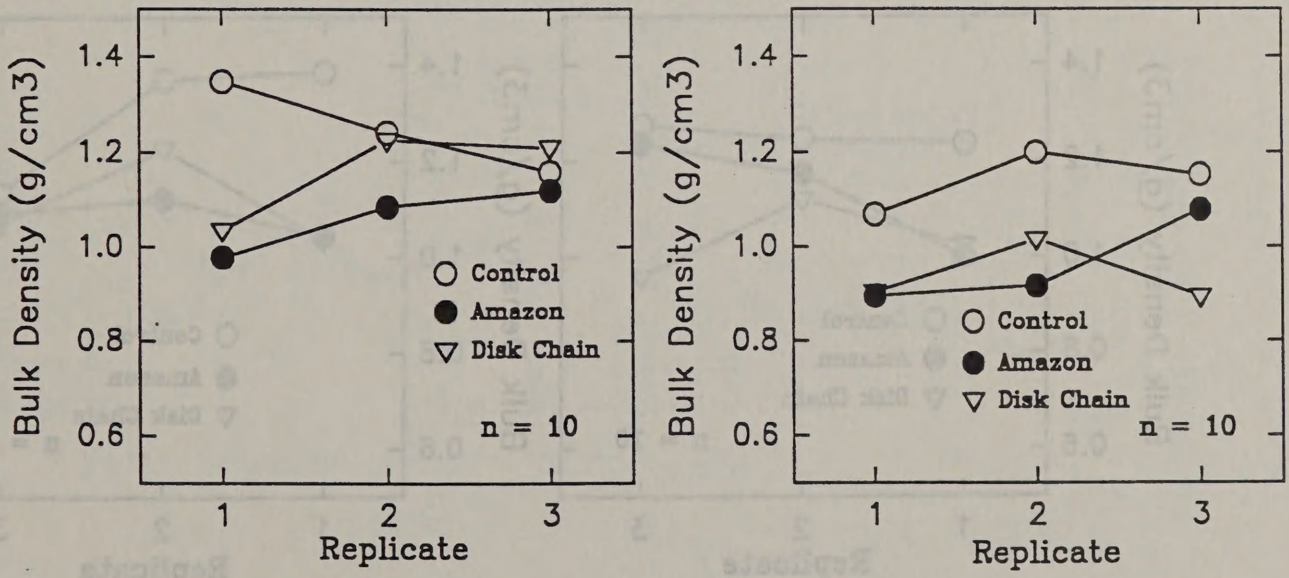
R. Sampled 08/01/91

Figure AI.2 (A-AA) Continued



S. Sampled 10/01/91

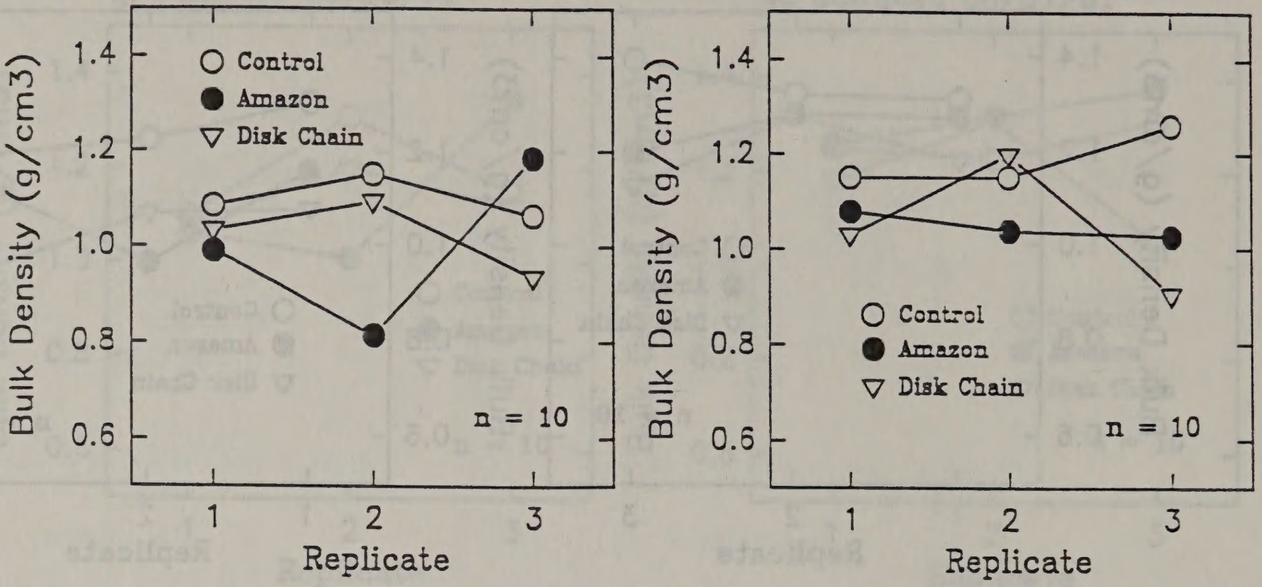
T. Sampled 11/05/91



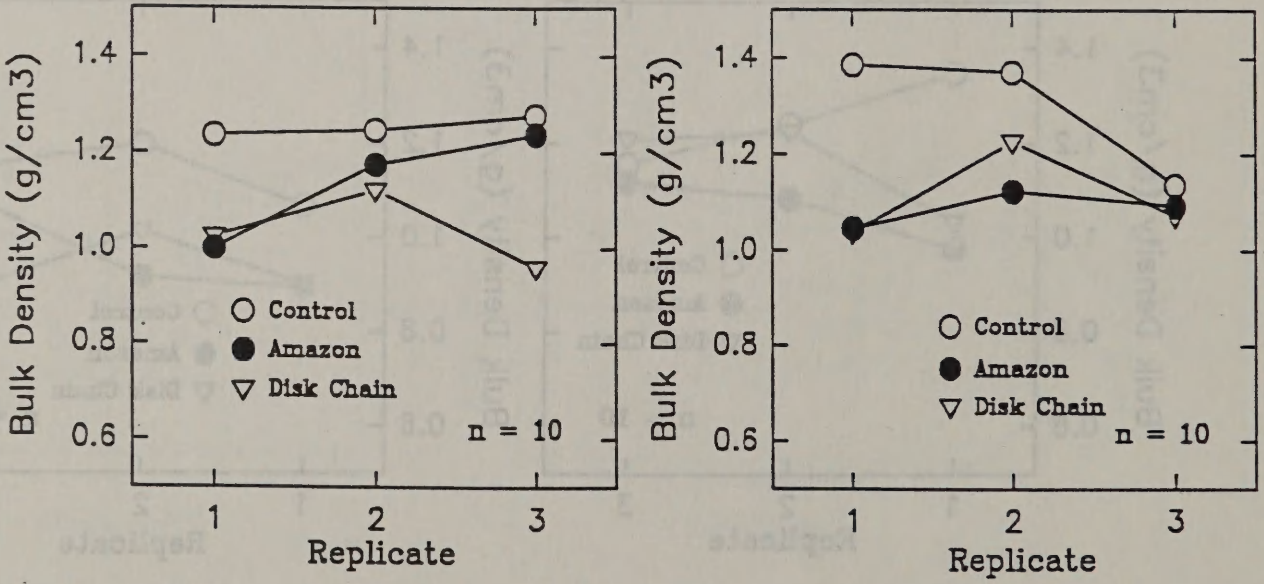
U. Sampled 12/06/91

V. Sampled 01/02/92

Figure AI.2 (A-AA) Continued


W. Sampled 02/01/92

X. Sampled 03/05/9291


Y. Sampled 04/02/92

Z. Sampled 05/08/92

Figure AI.2 (A-AA) Continued

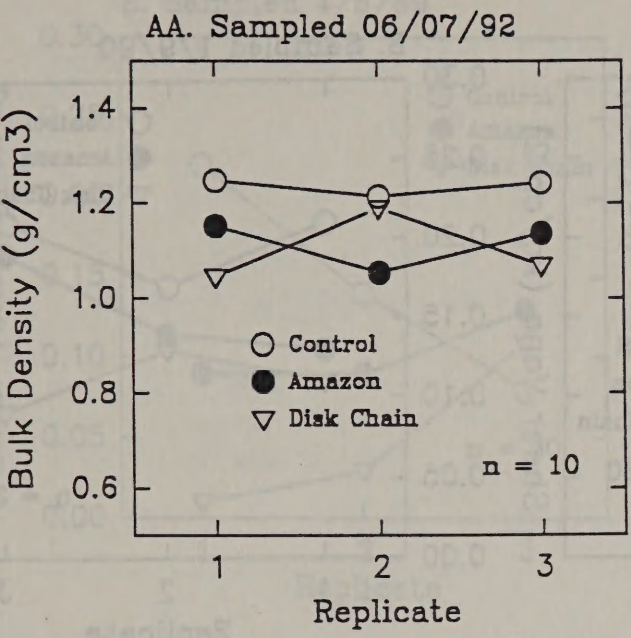


Figure AI.2 (A-AA) Continued

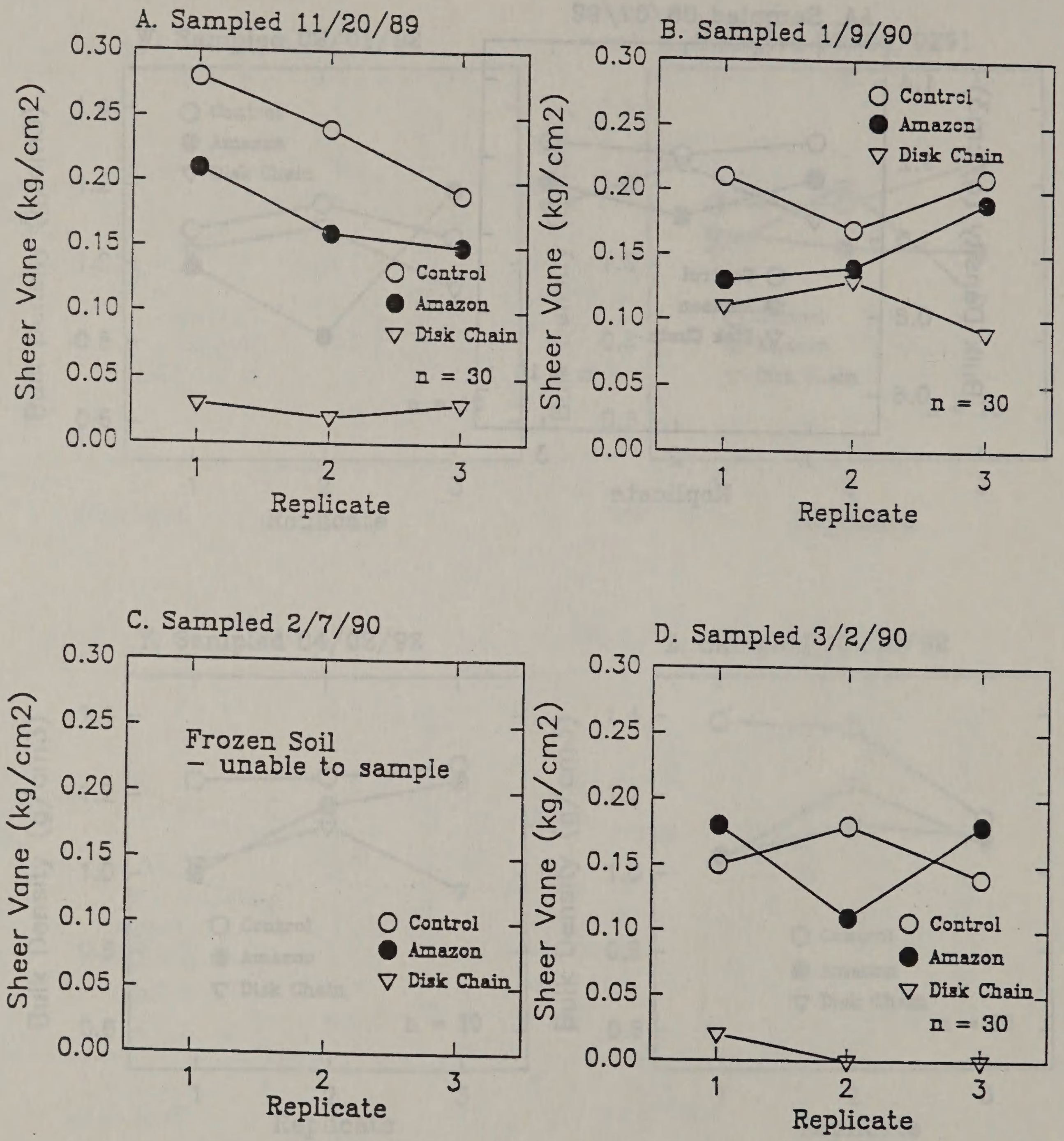
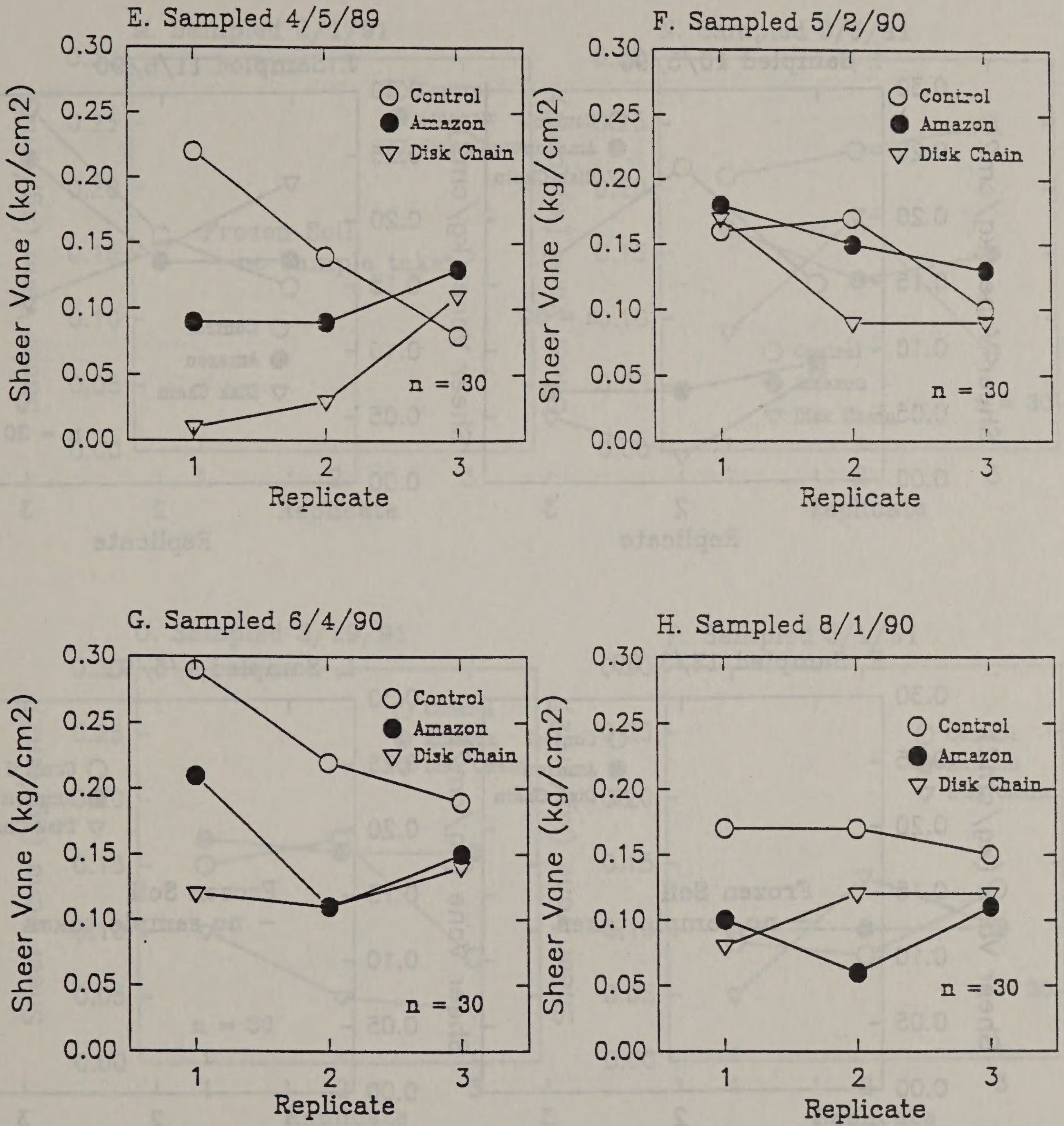


Figure AI.3 (A-AA) Sheer vane replicates for each sampling date (1989-1992). Greenstripping, permanent transects.


E. Sampled 4/5/89

F. Sampled 5/2/90

G. Sampled 6/4/90

H. Sampled 8/1/90

Figure AI.3 (A-AA) Continued

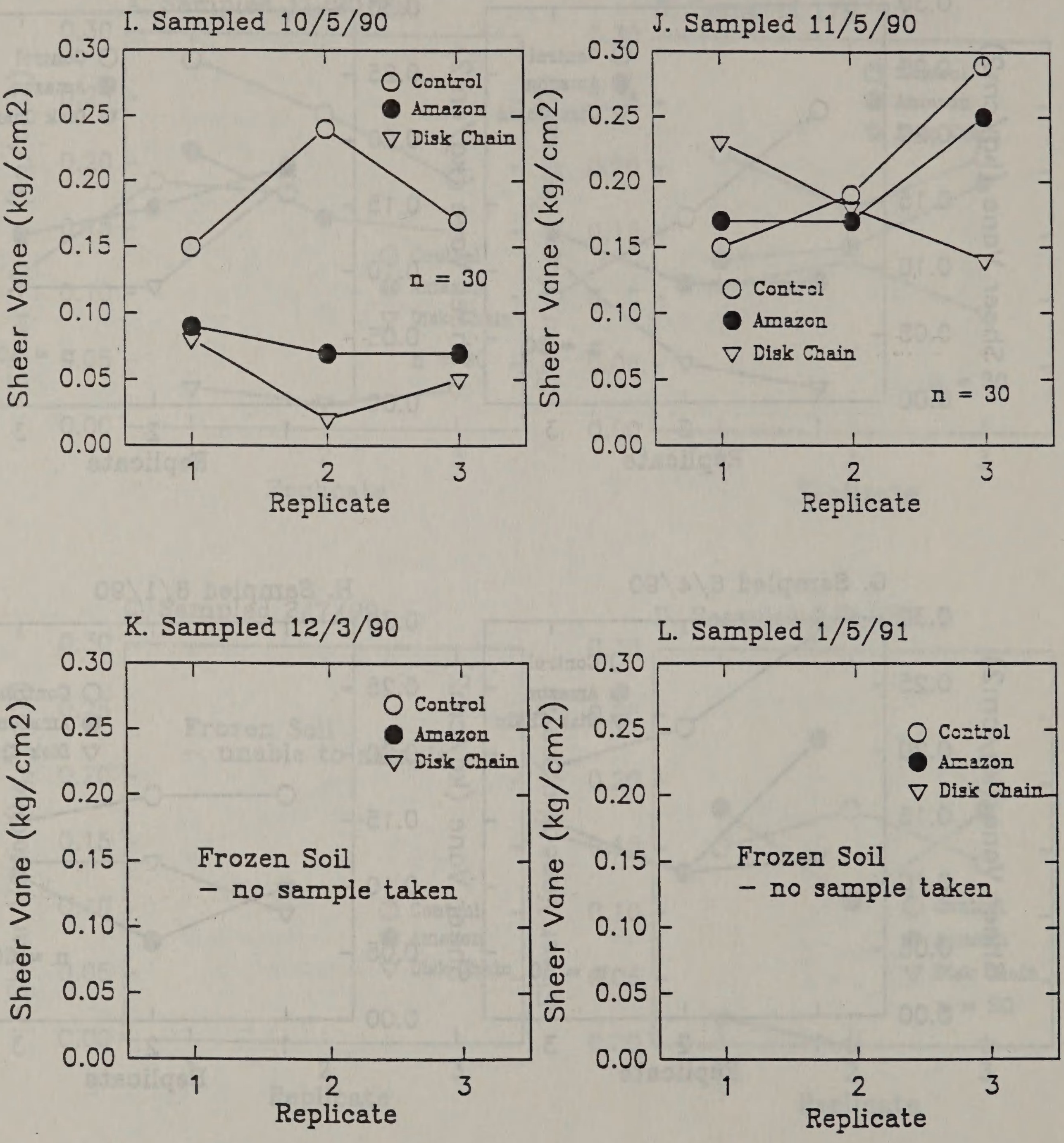
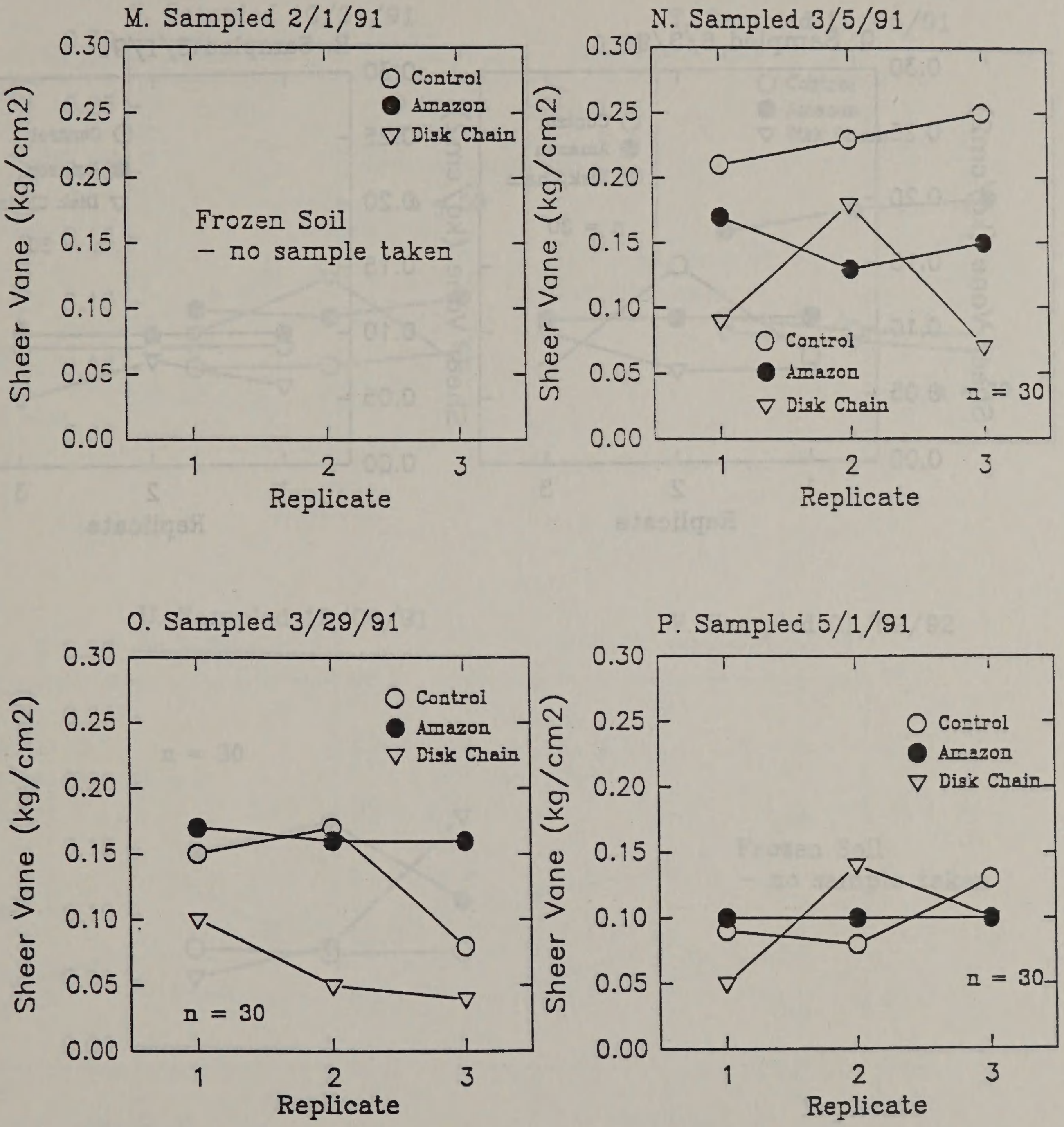


Figure AI.3 (A-AA) Continued



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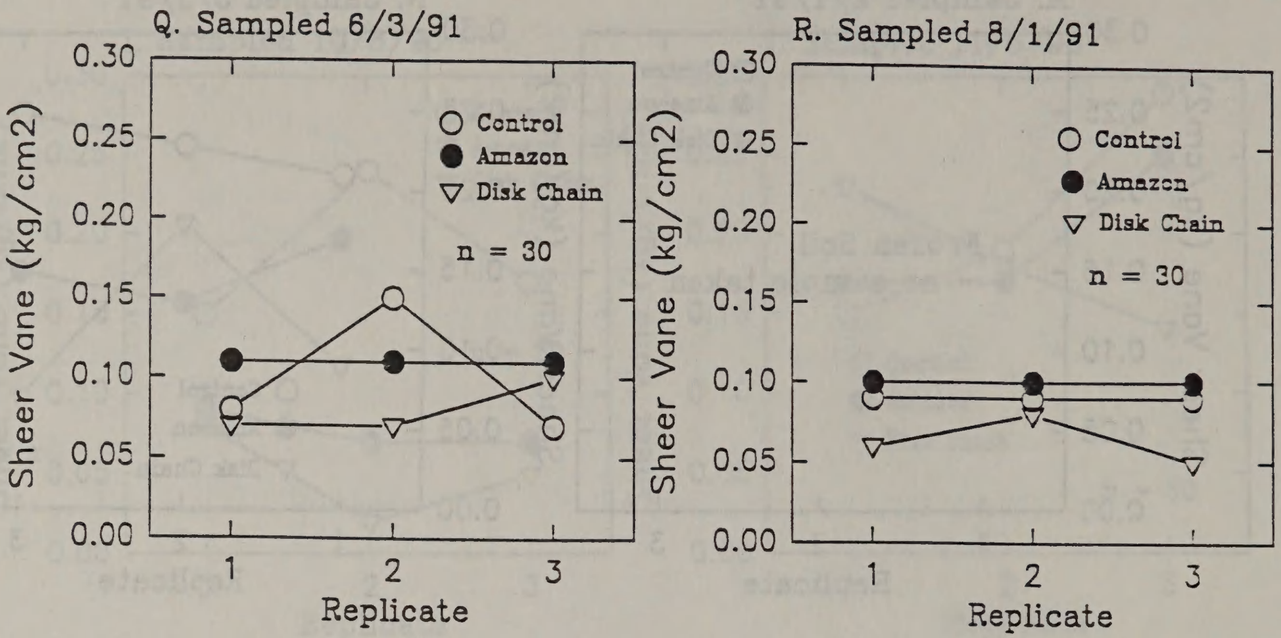
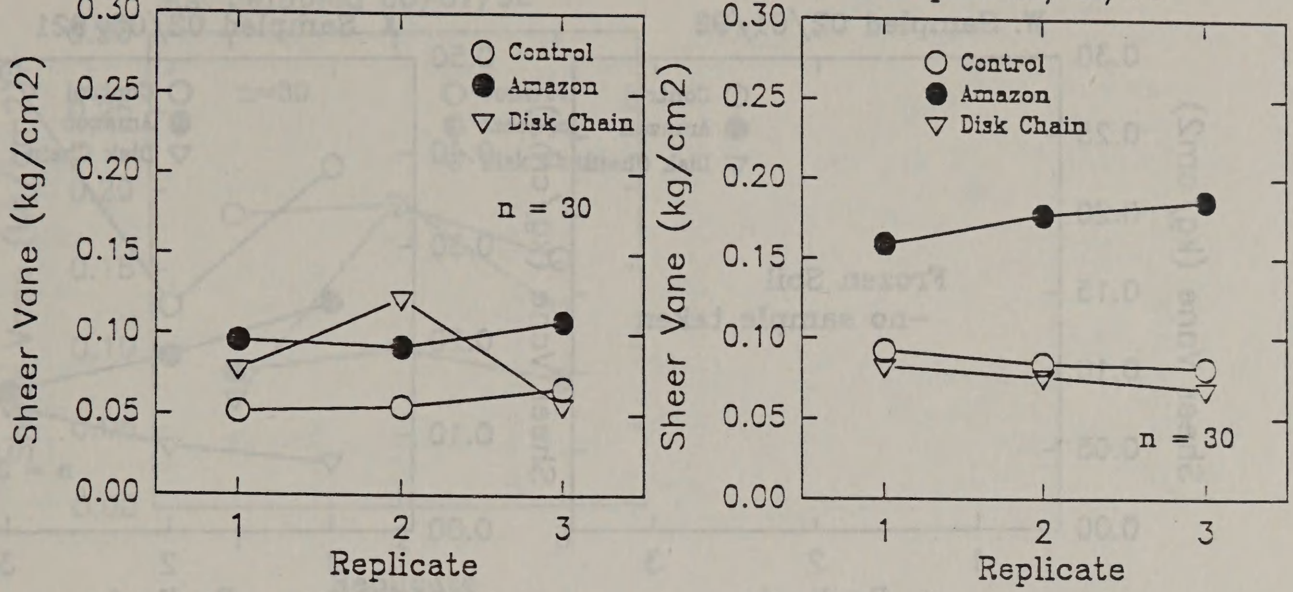

Q. Sampled 6/3/91

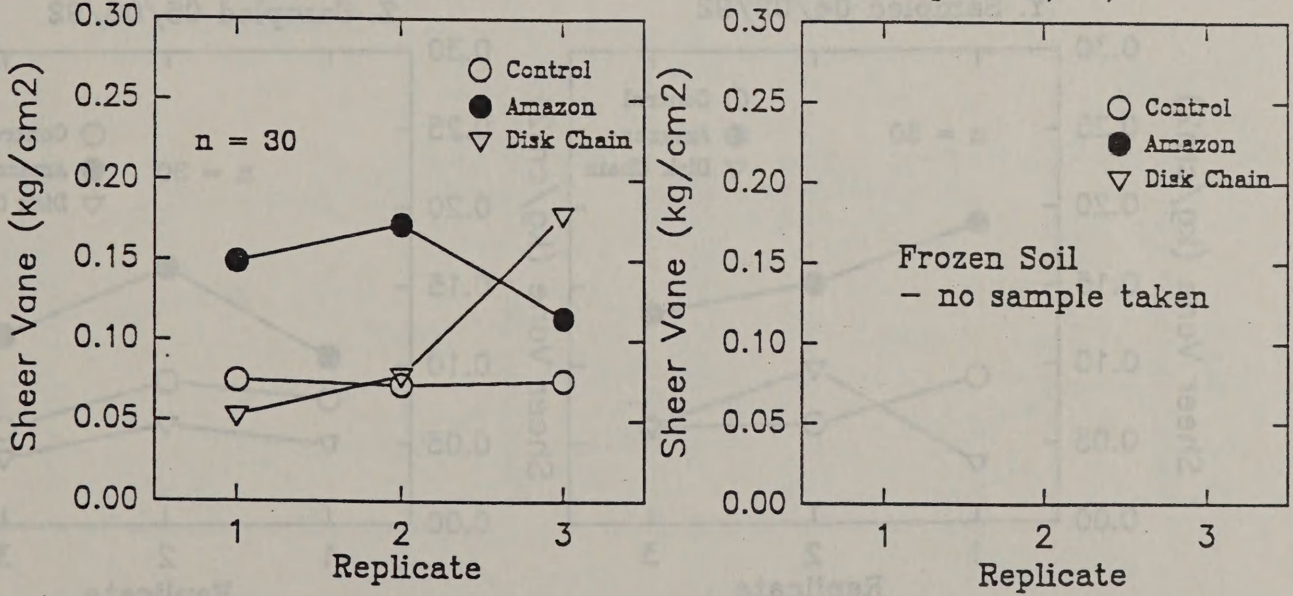
R. Sampled 8/1/91

Figure AI.3 (A-AA) Continued



S. Sampled 10/01/91

T. Sampled 11/05/91



U. Sampled 12/06/91

V. Sampled 01/02/92

Figure AI.3 (A-AA) Continued

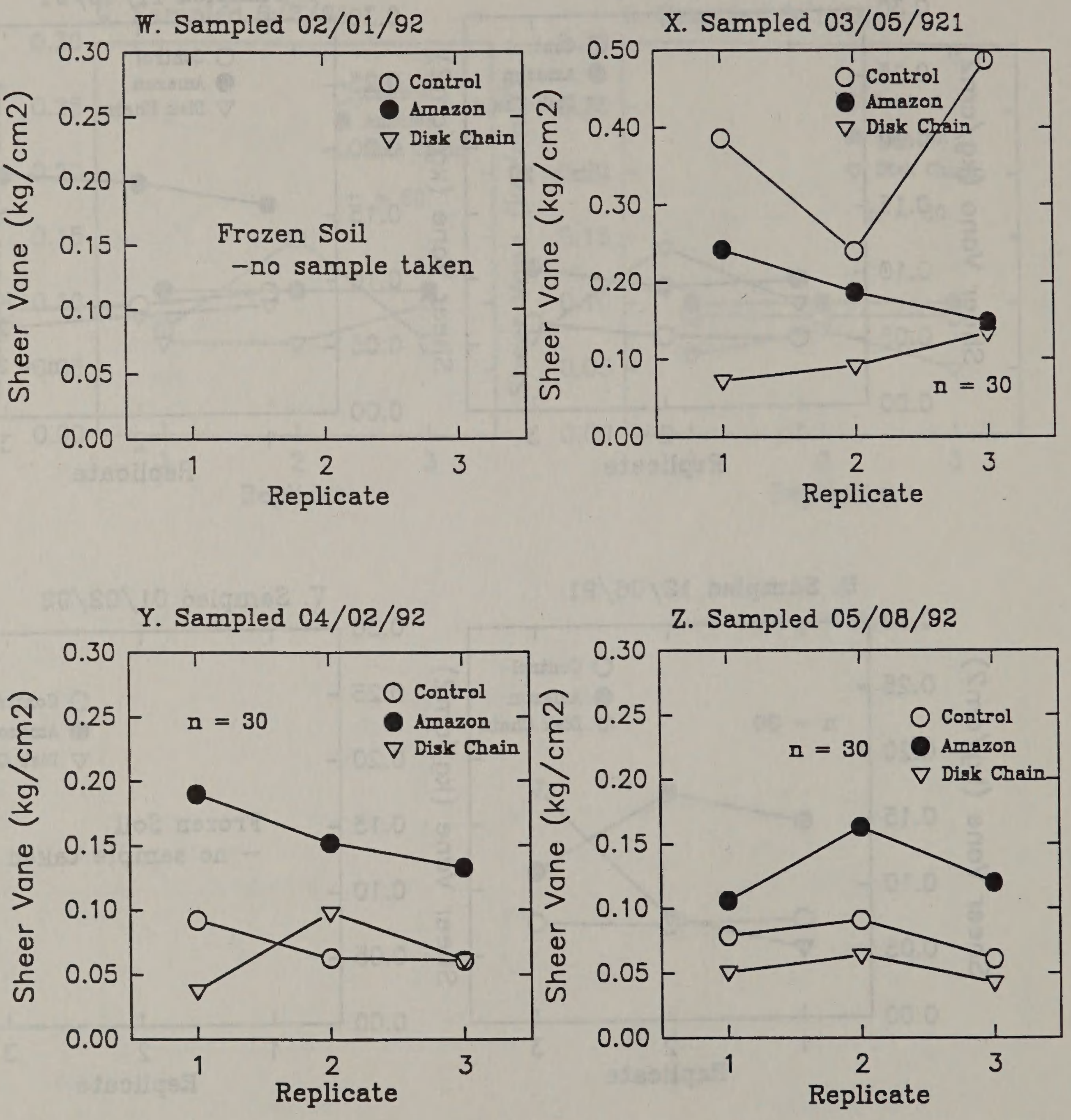


Figure AI.3 (A-AA) Continued

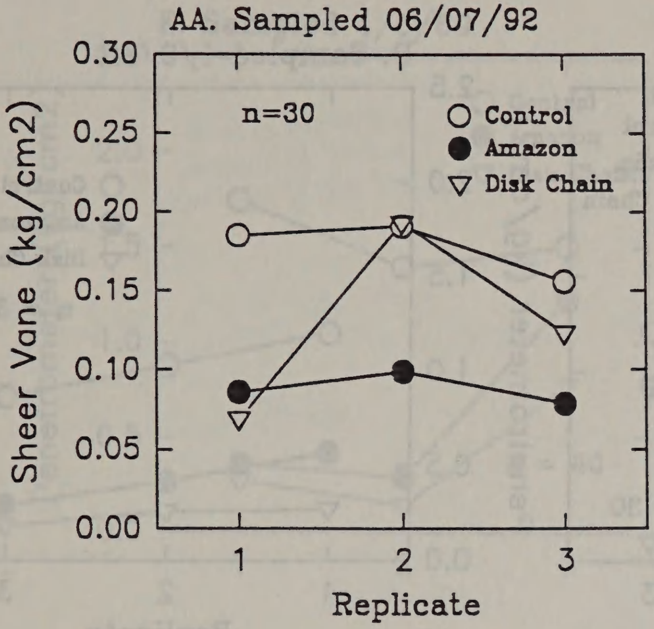
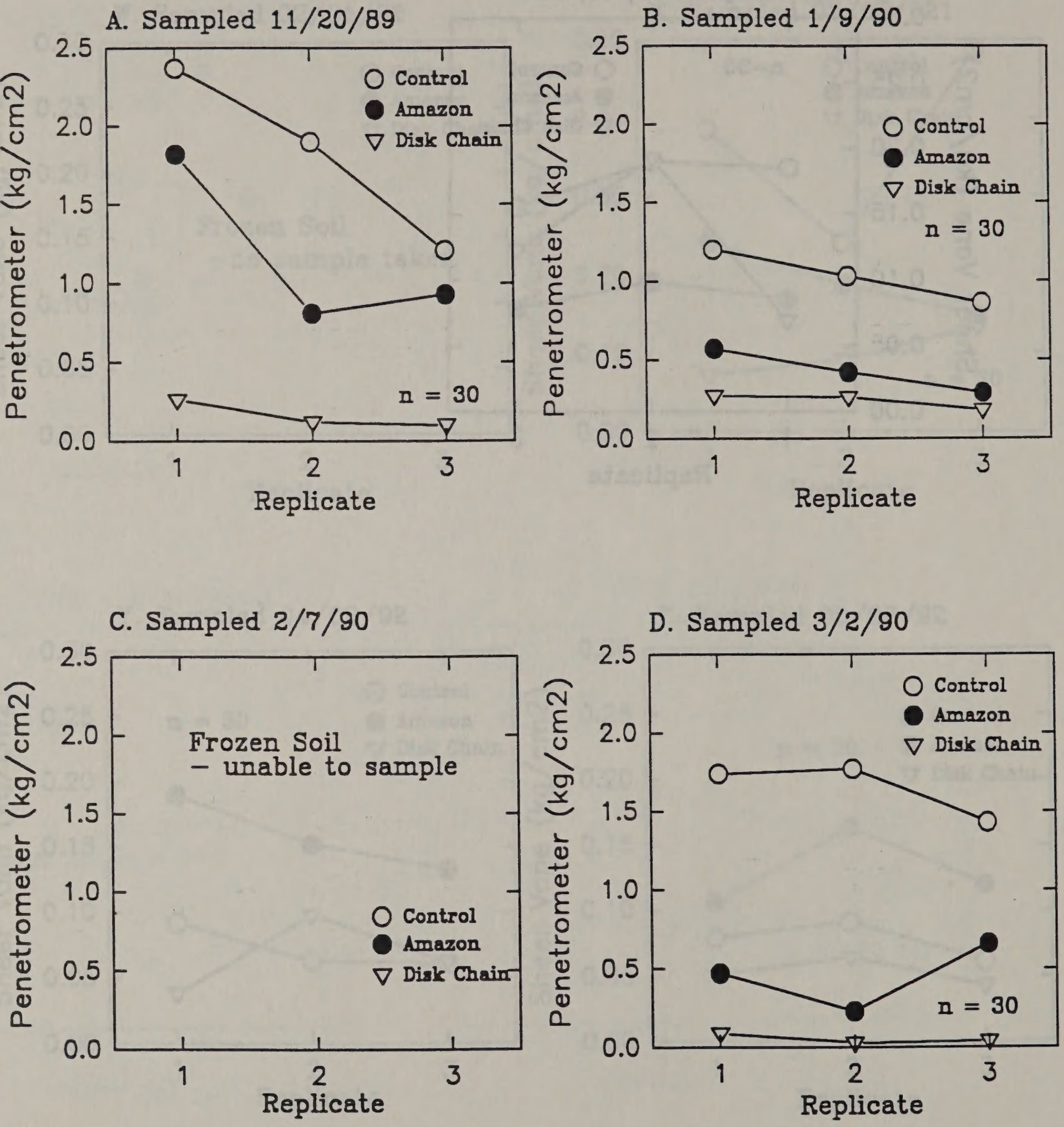


Figure AI.3 (A-AA) Continued



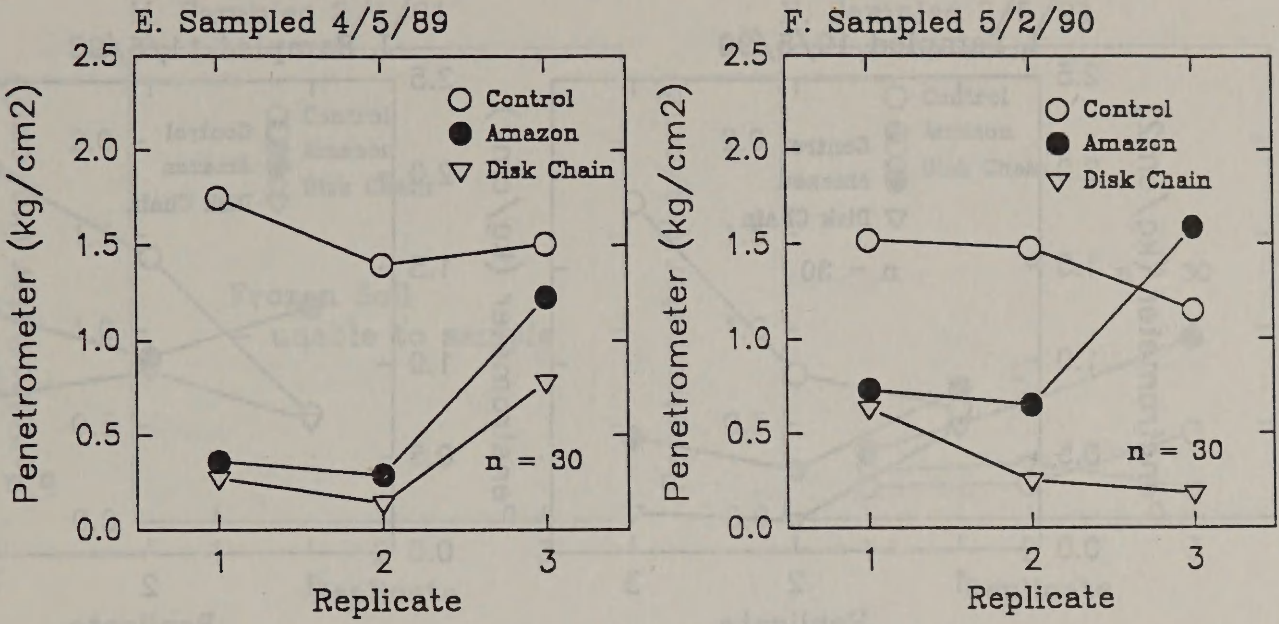
A. Sampled 11/20/89

B. Sampled 1/9/90

C. Sampled 2/7/90

D. Sampled 3/2/90

Figure AI.4 (A-AA) Penetrometer replicates for each sampling date (1989-1992). Greenstripping, permanent transects.



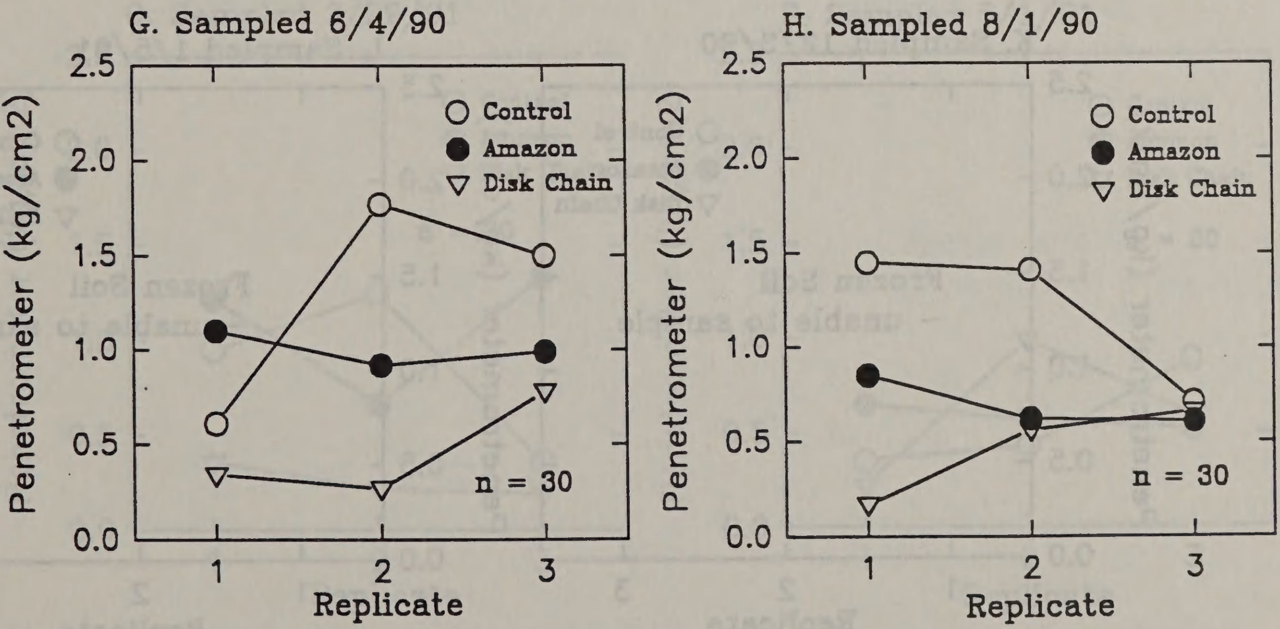


Figure AI.4 (A-AA) Continued

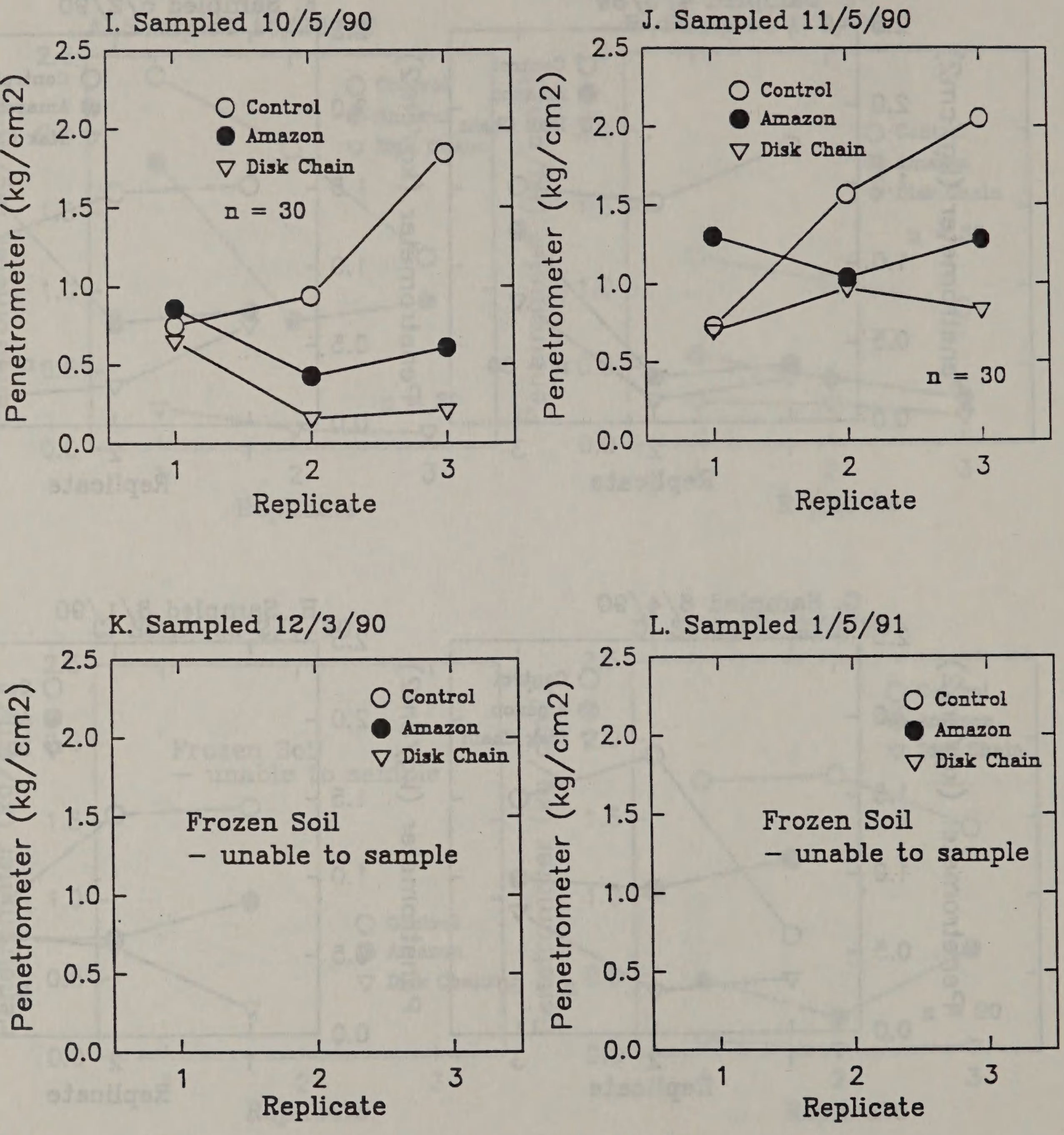


Figure AI.4 (A-AA) Continued

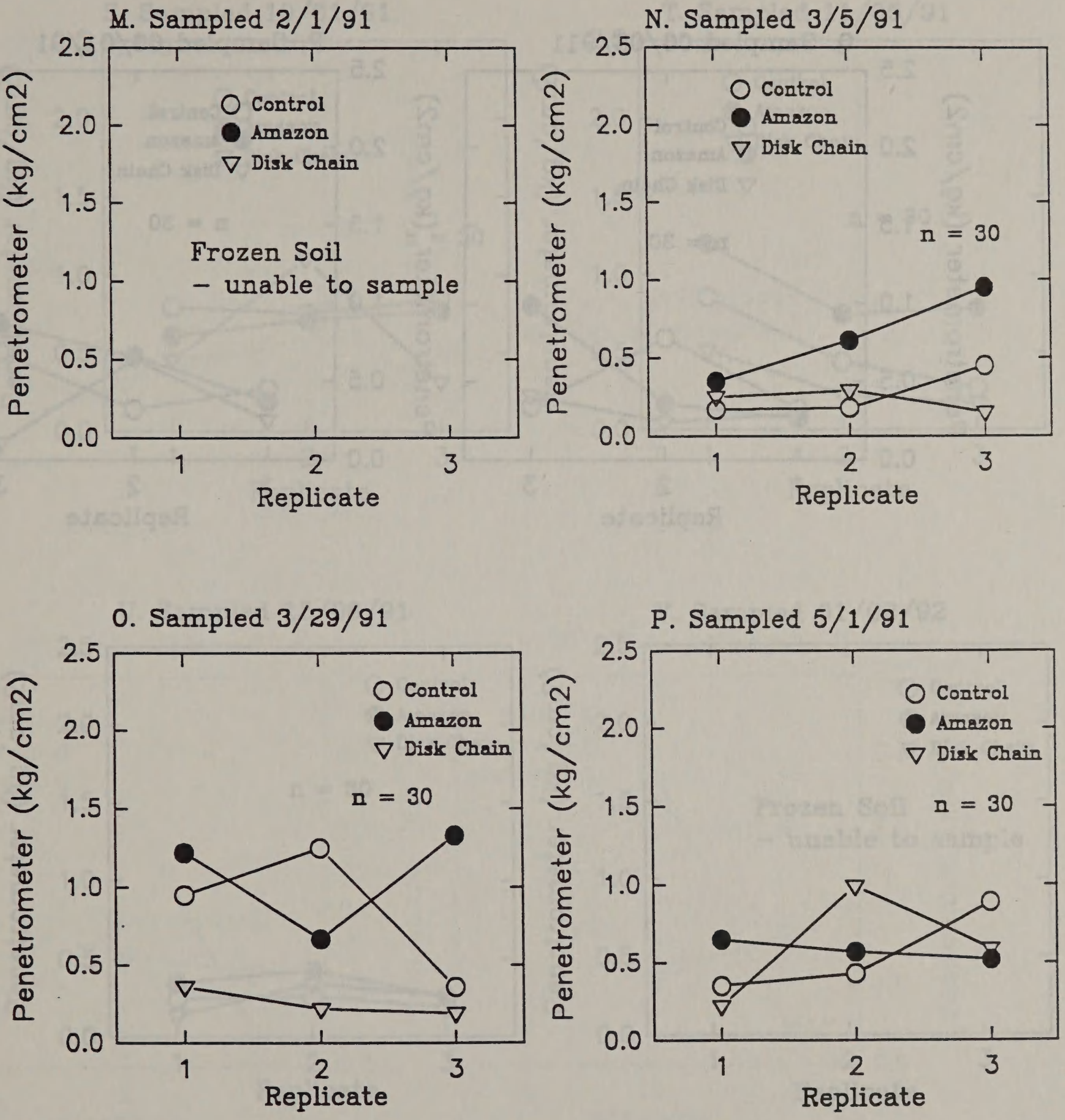


Figure AI.4 (A-AA) Continued

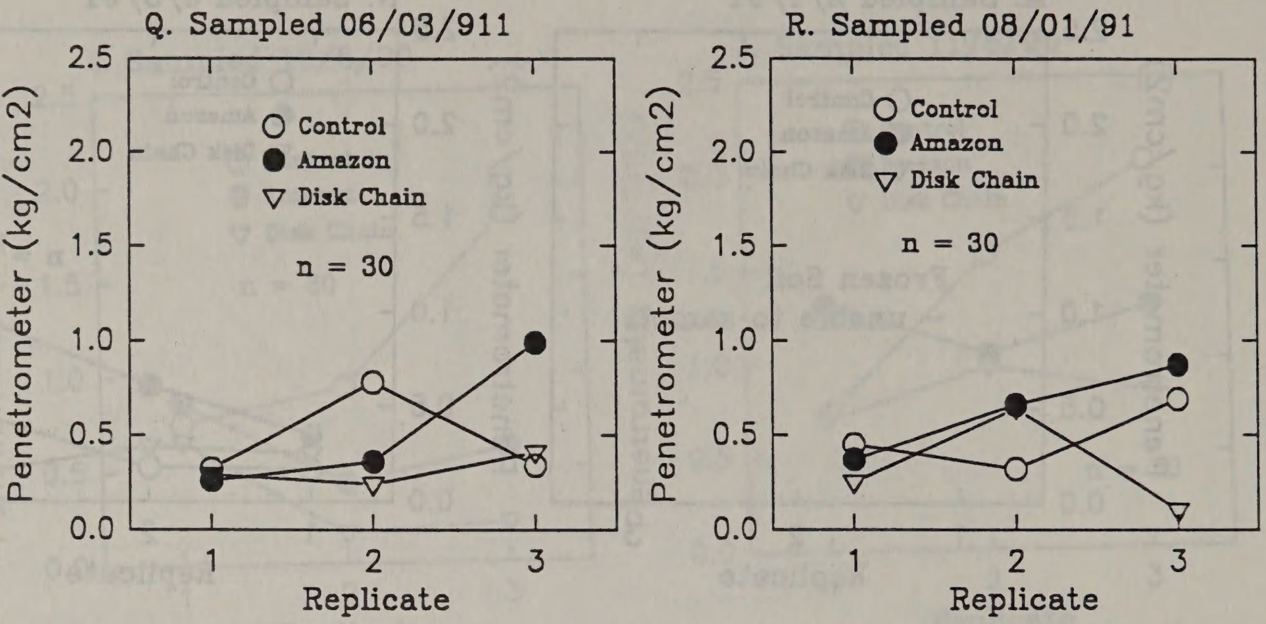
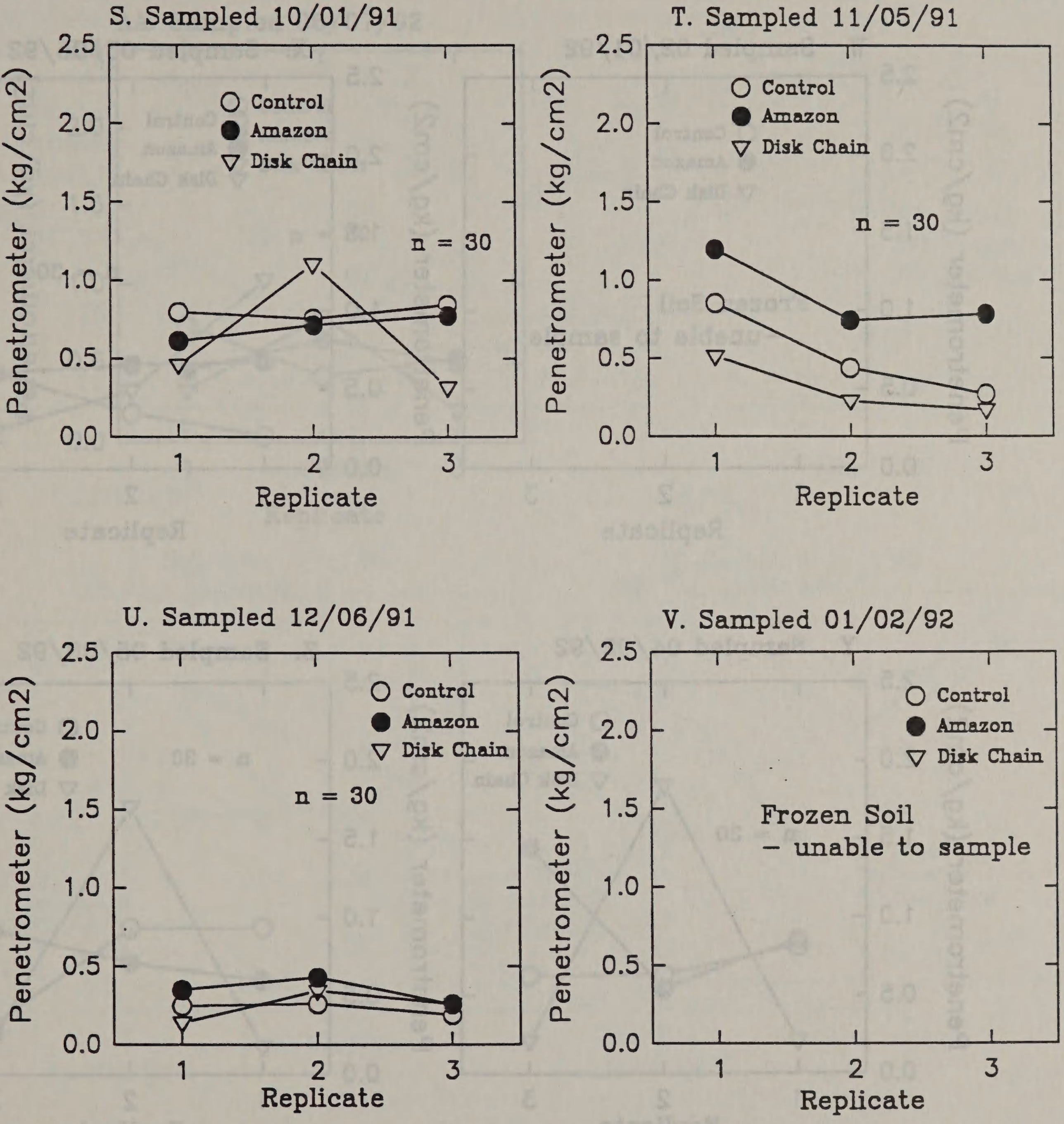


Figure AI.4 (A-AA) Continued


S. Sampled 10/01/91

T. Sampled 11/05/91

U. Sampled 12/06/91

V. Sampled 01/02/92

Figure AI.4 (A-AA) Continued

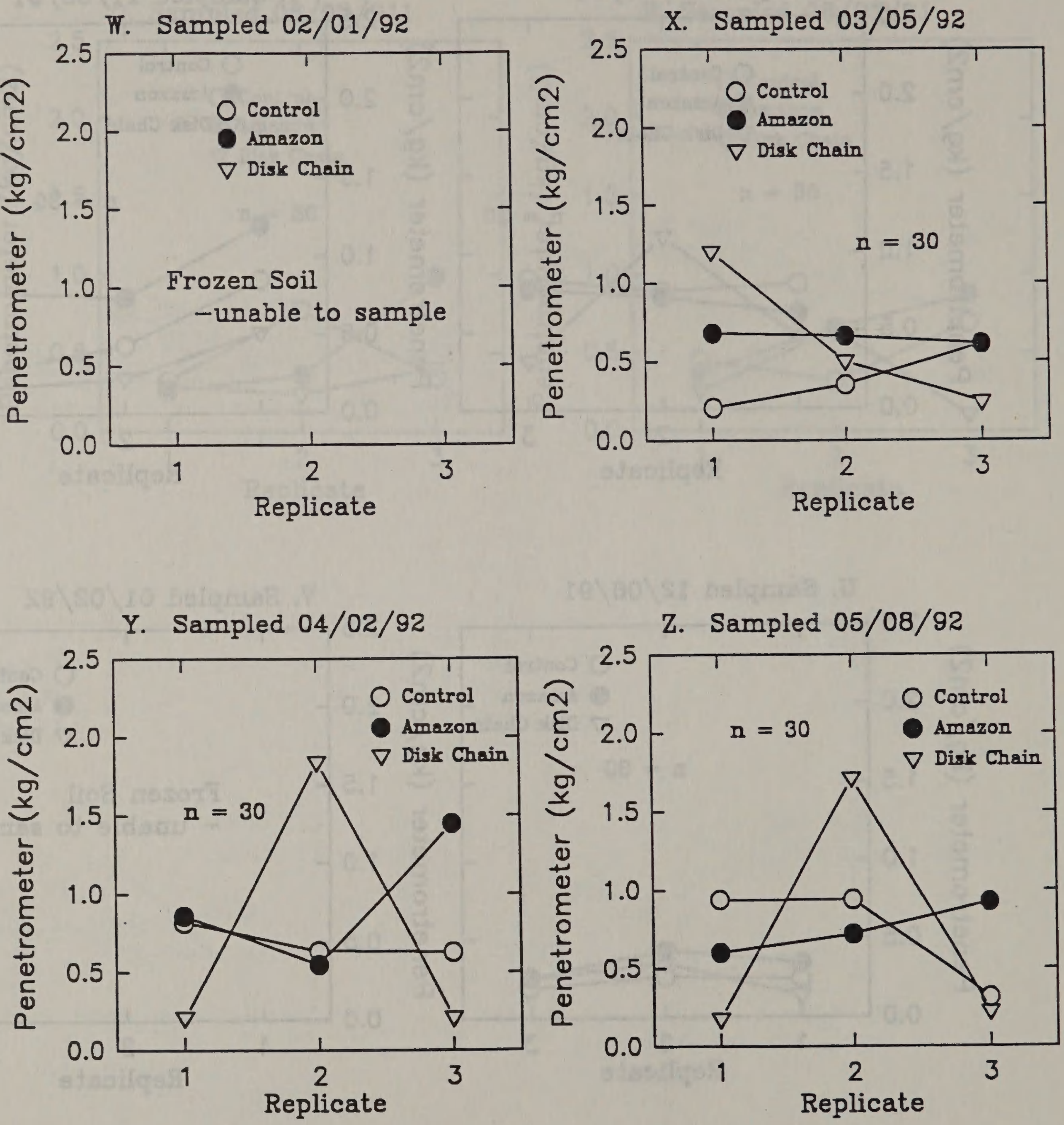


Figure AI.4 (A-AA) Continued

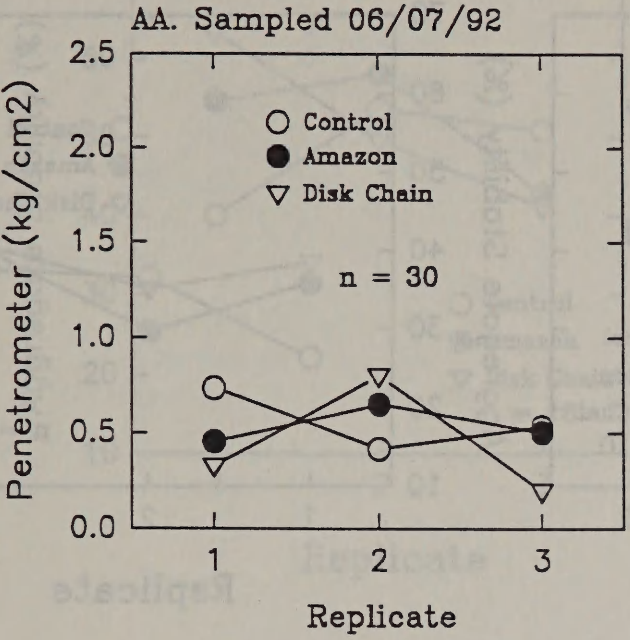


Figure AI.4 (A-AA) Continued

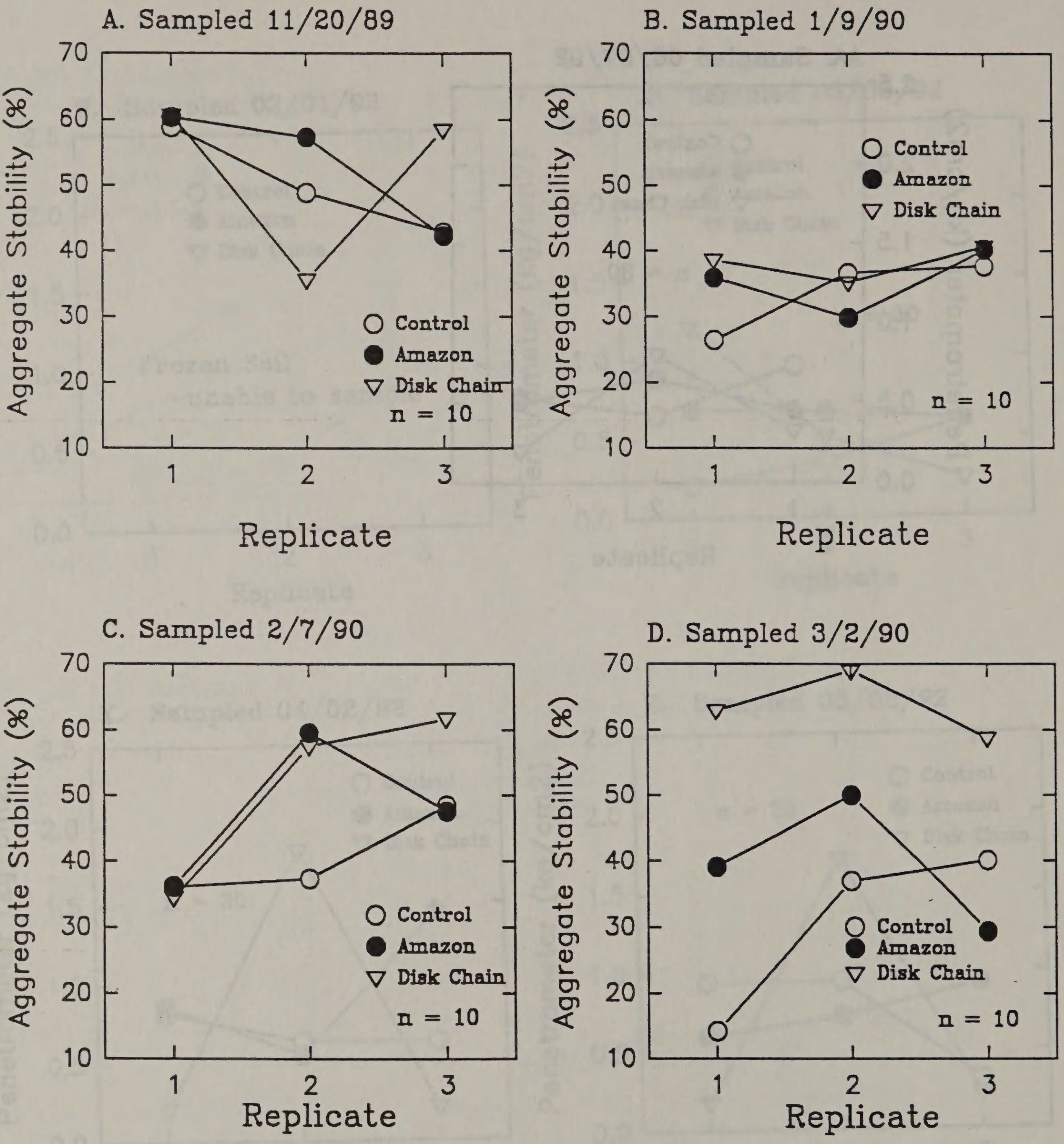
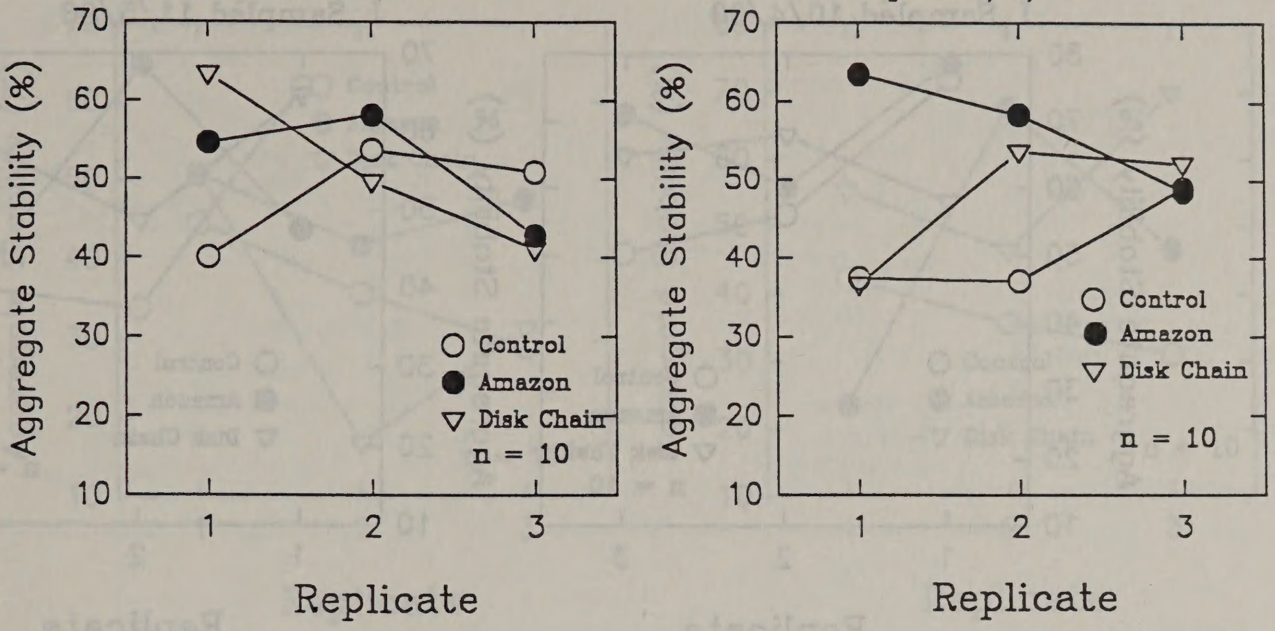
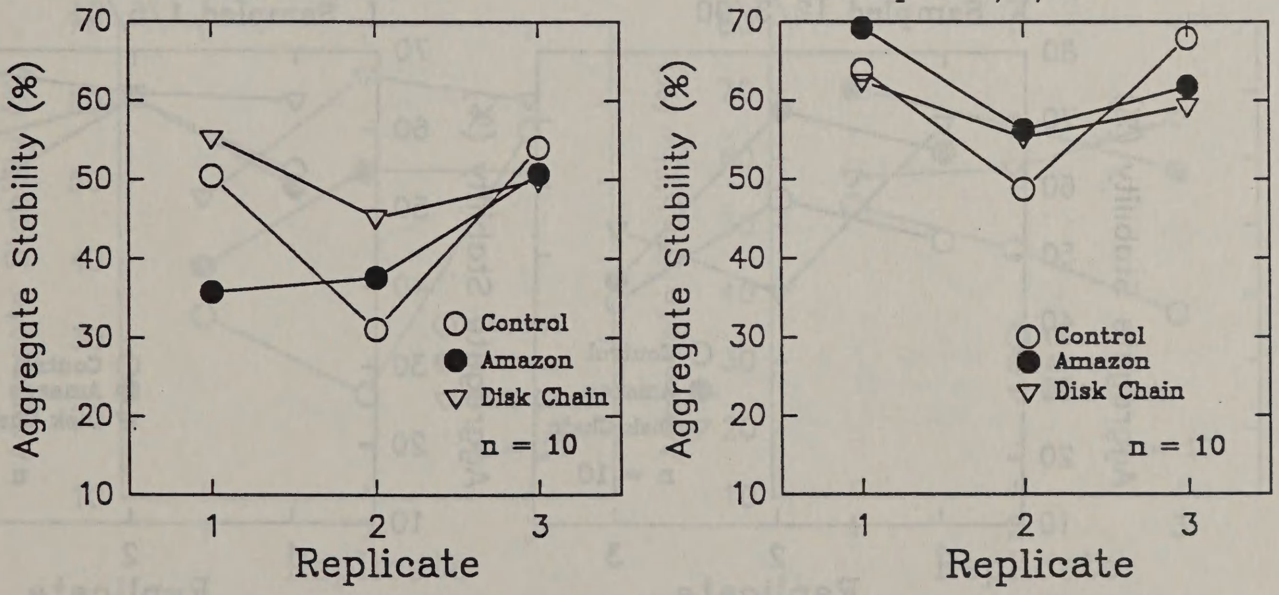


Figure AI.5 (A-AA) Aggregate stability replicates for each sampling date (1989-1992). Greenstripping, permanent transects.



E. Sampled 4/5/89

F. Sampled 5/2/90



G. Sampled 6/4/90

H. Sampled 8/1/90

Figure AI.5 (A-AA) Continued

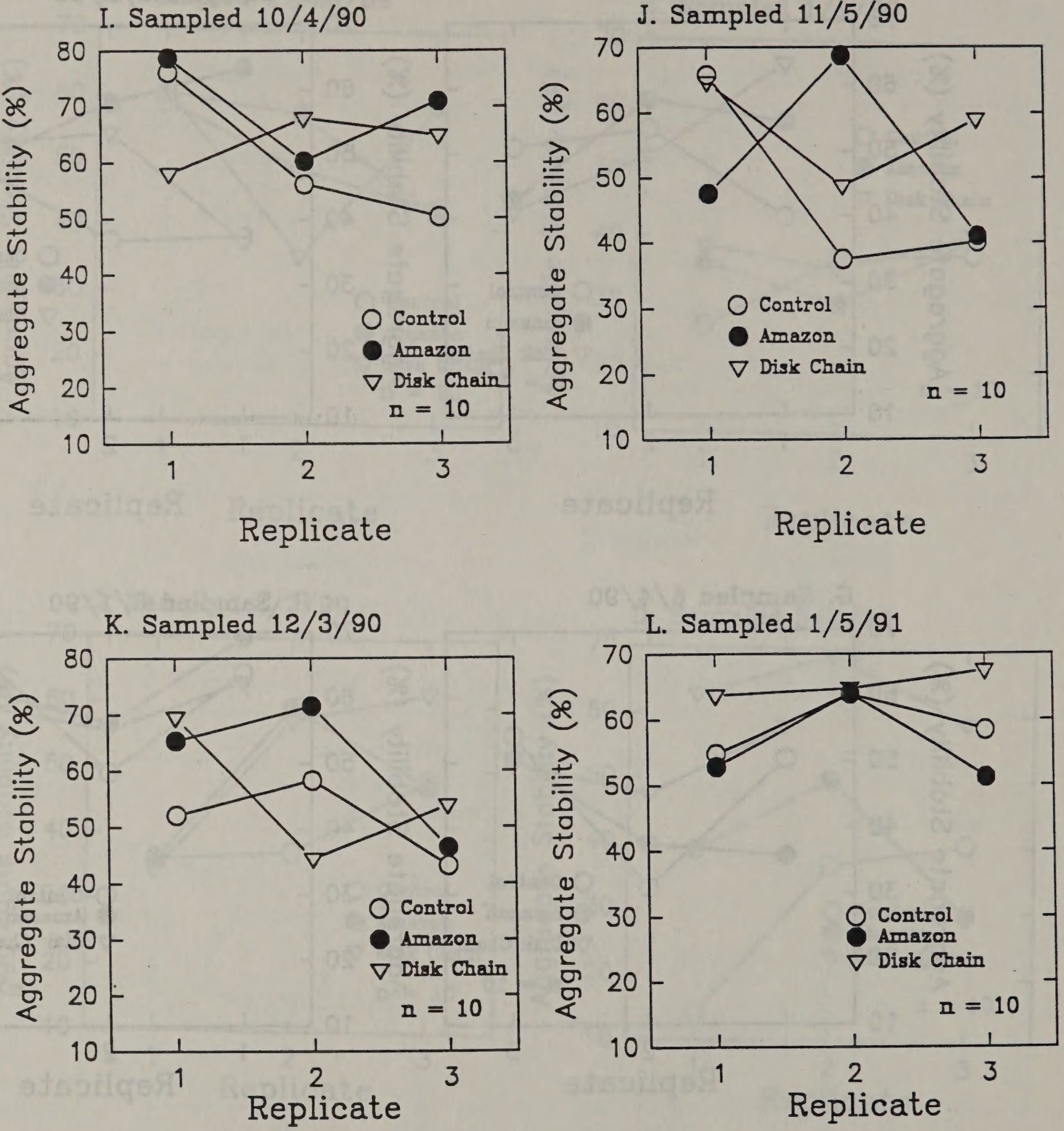


Figure AI.5 (A-AA) Continued

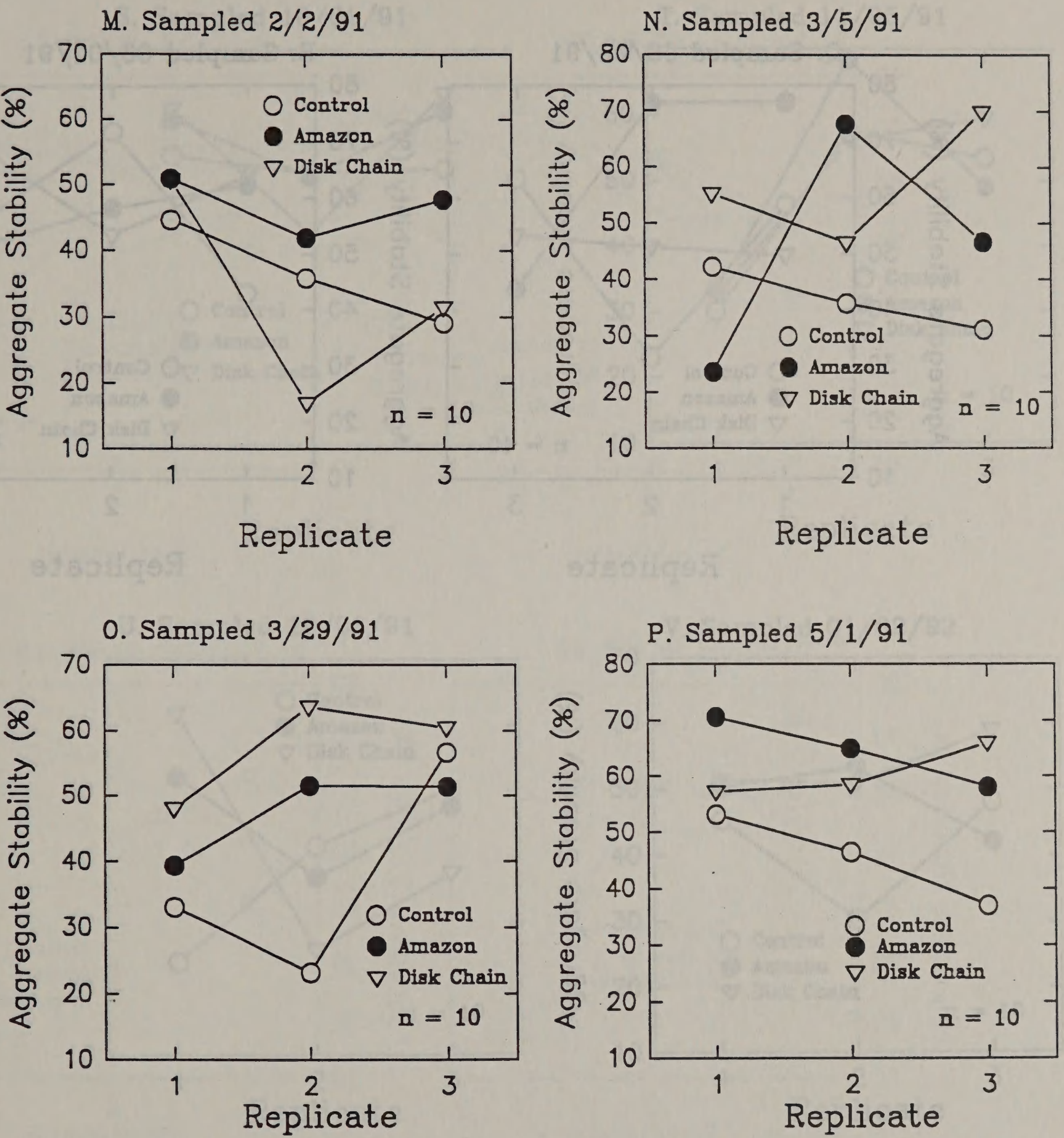
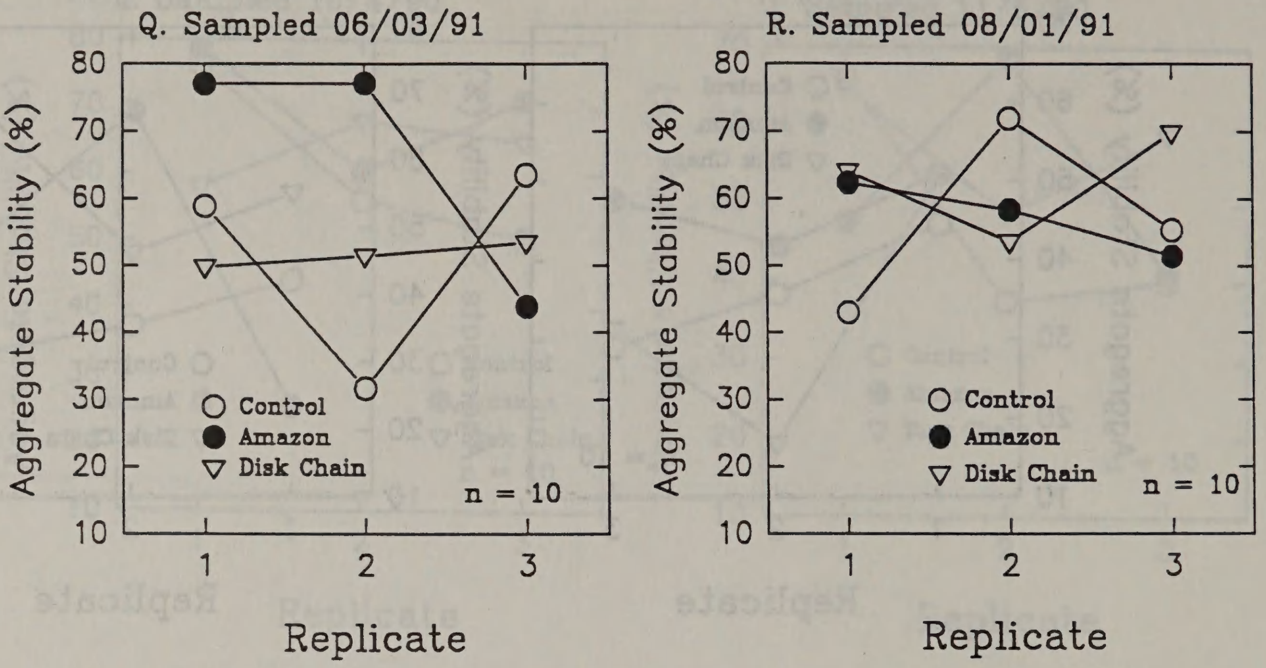
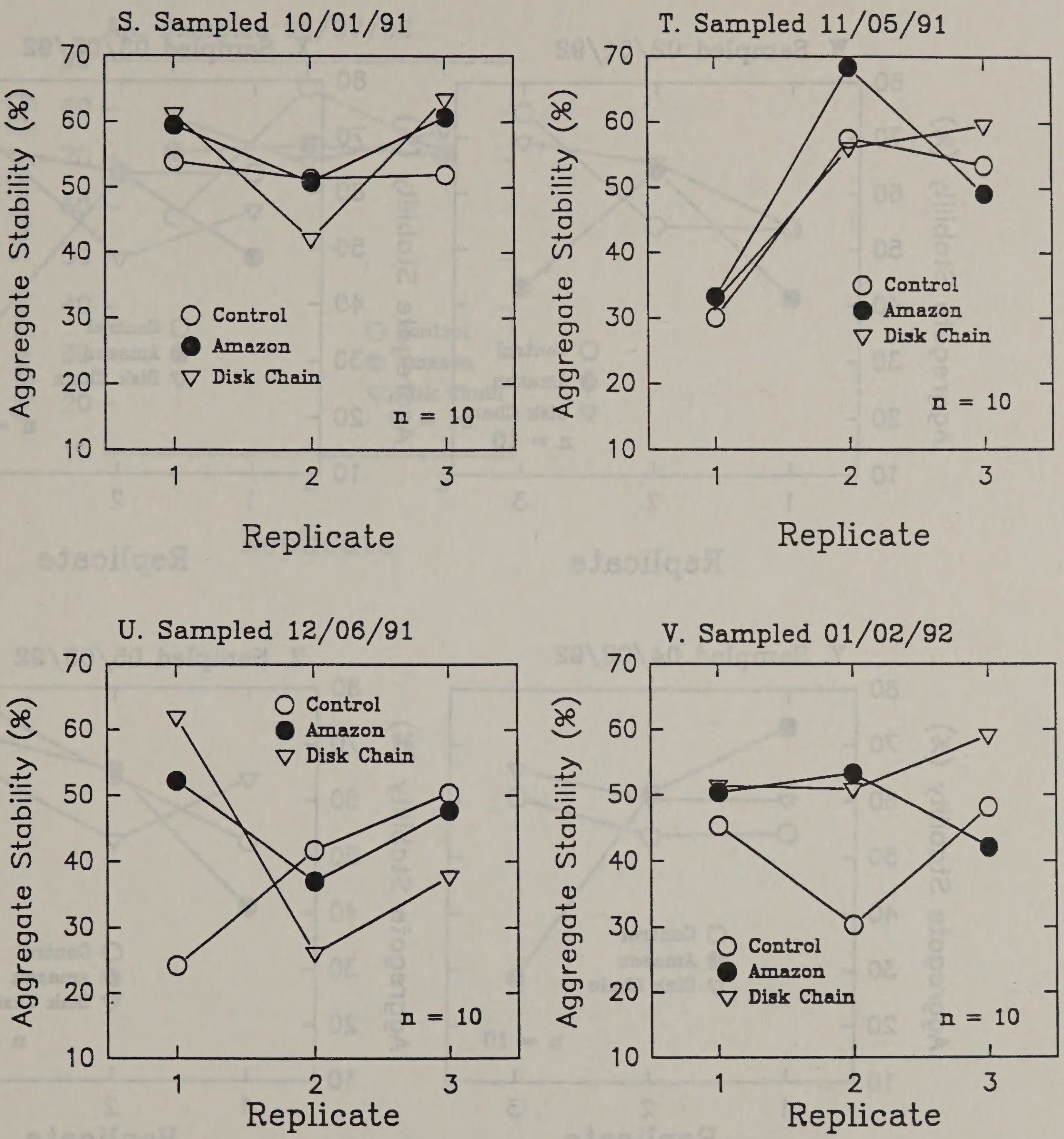


Figure AI.5 (A-AA) Continued


Q. Sampled 06/03/91

R. Sampled 08/01/91

Figure AI.5 (A-AA) Continued


S. Sampled 10/01/91

T. Sampled 11/05/91

U. Sampled 12/06/91

V. Sampled 01/02/92

Figure AI.5 (A-AA) Continued

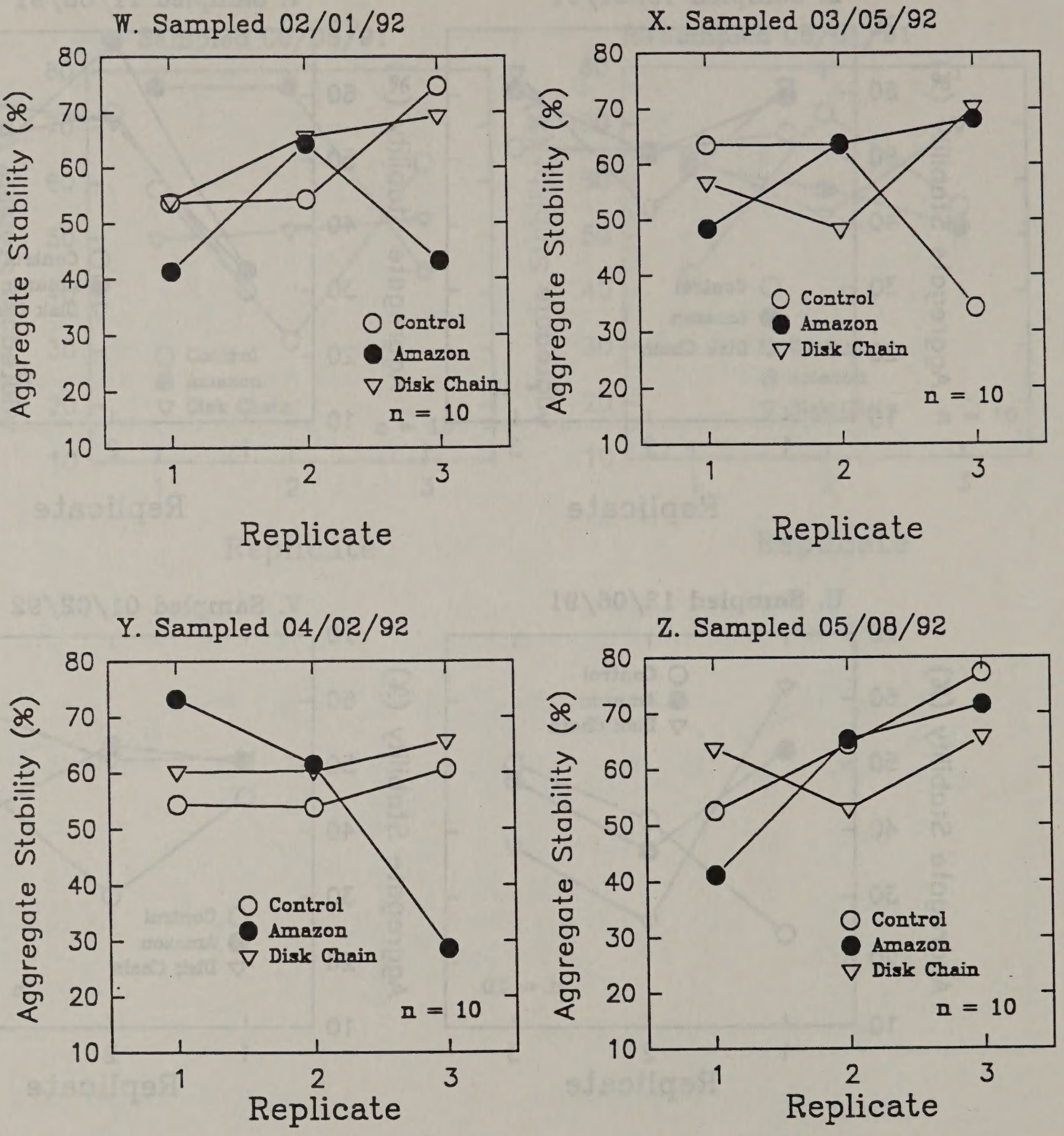


Figure AI.5 (A-AA) Continued

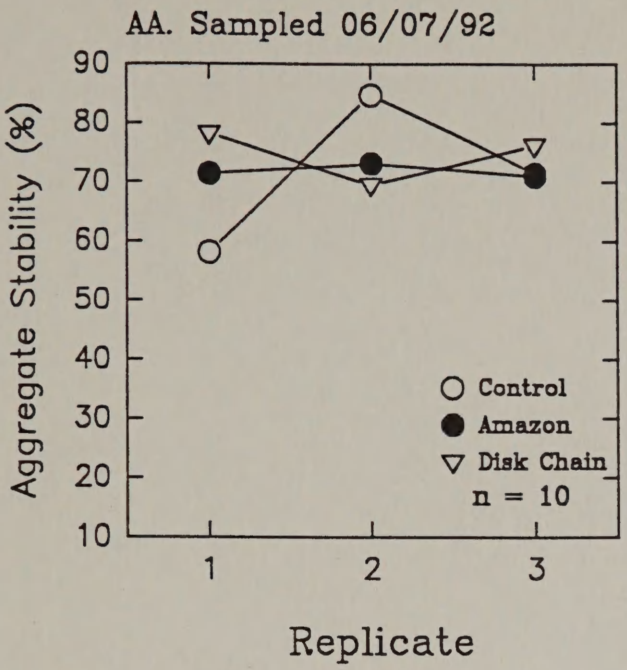


Figure AI.5 (A-AA) Continued

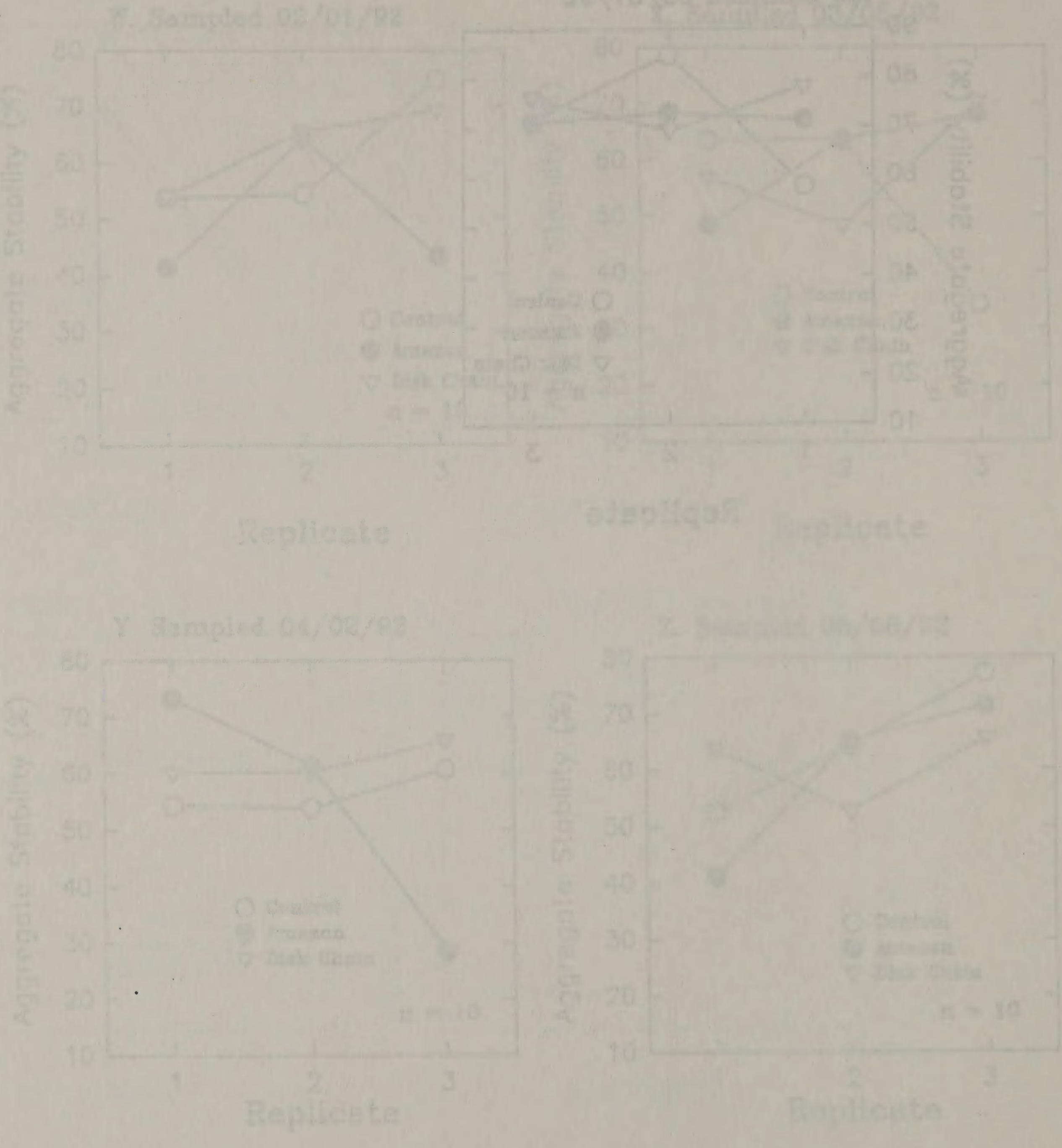


Figure A1.5 (A-AA) Continued